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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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EXAMINATION OF LOCAL KAOLIN FOR USE AS PAPER FILLER

POLYTECHNA
Prague

RESEARCH INSTITUTE FOR
CERAMICS, REFRACTORIES AND
NON-METALLIC RAW MATERIALS
Pilsen

CZECHOSLOVAKIA

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ABSTRACT

Tests of seven samples of raw kaolins from Burma were conducted as subcontract of the UNIDO project DP/BUR/85/017 "Examination of Local Kaolin for Use as Paper Filler". The kaolin was classified by washing in a laboratory pilot plant and particular fractions of washing were tested and evaluated. Suitable areas of application were specified for the Burmese kaolins.

Some of the samples represent a raw material of lower quality, especially as regard to their whiteness, and complex upgrading methods have to be applied for their upgrading. Whiteness of kaolins Shwe Daung, Wellan, Kadatdauk, Maukmar and Yoezayat can be increased by chemical bleaching which is the most successful method of this purpose. After upgrading the kaolins can be used as paper fillers of medium quality. Washed kaolins Mabizan and Kyauktaga have a sufficient whitness (about 71%) and they can be used as paper fillers without bleaching. All the kaolins tested can be utilized in different branches of ceramic industry.

Besides laboratory and pilot plant testing the suitable technologies of upgrading were recommended for each kaolin.

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I. INTRODUCTION

The suitability of the delivered Burmese kaolin samples for the paper making and testing of suitable upgrading methods for increasing of whiteness were the principal objectivesof the tests conducted. The samples represented raw materials recently found in Burma which were predetermined as substitute for the imported fillers for Burmese paper industry which is expected to expand in near future.

In principle, there are two applications for kaolinitic minerals in the paper making - as fillers or as coating agents.The testing programme was, therefore set up so as to make possible to investigate gradually all the decisive paramaters for the above applications. The kaolin samples were washed in three basic fractions according to grain size distribution and the main effort was concentrated on the paper making appropriate clay fraction. The parameters watched were the grain size distribution, whiteness, abrasivity and the possibility of upgrading by industrial mineral processing methods.

Good quality coating kaolins are required to have about 90 per cent of particles in the range under 2 microns and maximum 10 per cent of particles above 10 microns; their abrasivity is usually 10 mg or less and brightness above 80%. The requirements for the fillers are less strict; about 55% per cent of particles under 2 microns, abrasivity accounting for 25 - 40 mg and whiteness 75 per cent and more.

The testing programme included all the tests specified in the contract to be carried out:

- chemical and mineralogical analyses in a raw state
- washing of raw kaolin to separate:
  - a) sandy fraction
  - b) silty fraction
  - c) clay fraction

- chemical and mineralogical analyses of fractions a, b, c.
- grain size distribution of fractions a, b, c
- technological properties of fractions a, b, c
- chemical bleaching, magnetic separation and delamination of fraction c.

Based on the results of the above tests the quality of the samples was evaluated from the point of view of paper making and ceramic production, the results were concluded and relevant actions and upgrading technologies were recommended.

II. CONCLUSIONS AND RECOMMENDATIONS

1. SHWE DAUNG

a) The tested kaolin can be classified as a raw material with medium content of kaolinite about 30%. Washed kaolin has a very low whiteness, the lowest one from the whole set of the samples. The kaolin is not suitable for an application in paper industry without further upgrading but it can be directly used in a ceramic idustry (sanitaryware, wall tiles, floor tiles, facade tiles, pottery, stoneware, artistic ceramics).

b) The kaolin can be treated especially by chemical bleaching. The final value of whiteness after bleaching is from 65 to 60%.

c) Sand as a by-product of washing can be used in a building industry. Silty fraction is utilizable in ceramic industry as a part of body mixtures in production of floor tiles, wall tiles, stoneware, pottery and artistic ceramics.

d) Following technology of upgrading is recommended for kaolin Shwe Daung:

- washing
- control sieving on the sieve 1.0 mm removing of sand and pebbles
- classification in hydrocyclones 150 mm (HYCY 150) for removing of fine-grained sand
- classification in hydrocyclones 50 mm (HYCY 50) for removing of silty fractions
- flocculation
- thickening
- filtration
- drying

2. WELLAN

a) The kaolin can be classified as a rich raw material with a yield of washing about 35%. Whiteness of the washed kaolin is low (only 65%). Abrasivity is suitable for an application in paper industry. The kaolin has a low strength, a higher content of Al_2O_3 (33%) and its colour after firing is white.

b) Whiteness of the kaolin can be increased by chemical bleaching (up to the value 72%), by magnetic separation (up to the value 68.5%) and partly by delamination (up to the value 66%). Utilization of the kaolin as a paper filler is possible after upgrading.

c) The washed kaolin without treatment can be used in a ceramic industry as a part of body mixtures in a production of wall tiles, floor tiles, facade tiles, sanitaryware, stoneware and pottery.

d) Following technology of upgrading is recommended for kaolin Wellan:

- washing
- control sieveing on the sieve 1.0 mm for removing of sand and pebbles
- classification in hydrocyclones 150 mm (HYCY 150) for removing of fine-grained sand
- classification in hydrocyclones 50 mm (HYCY 50) for removing of silty fraction
- flocculation
- thickening
- filtration
- drying

3. KADAT DAUK

a) The tested kaolin can be classified as a rich raw material with the yield of washing about 35%. Whiteness of washed kaolin is low - 59%, abrasivity is good - 15 mg. The kaolin has lower strength, colour after firing is grey.

b) Kaolin without upgrading (bleaching) cannot be recommended for applications in a paper industry, It can be used in ceramic industry for producion of tiles, stoneware, sanitaryware, pottery and artistic ceramics.

c) Chemical bleaching is the most effective method for increasing of whiteness of kaolin Kadatdauk, but the final whiteness reached is still low - 63%.

d) By-products of washing can be used in some industrial branches. Sand can be utilized (after classification) as a foundry sand in metallurgy and also in building industry for production of concrete and mortars. Silty fraction of washing is utilizable in ceramic industry as a component of body mixtures in the production of wall tiles, floor tiles, stoneware and pottery.

e) Following technology of upgrading is recommended for kaolin Wellan:

- washing
- control sieving on the sieve 1.0 mm for removing of sand and pebbles
- classification in hydrocyclones 150 mm (HYCY 150) for removing of fine-grained sand
- classification in hydrocyclones 50 mm (HYCY 50) for removing of silty fraction
- flocculation
- thickening
- filtration
- drying

4. MAUKMAI

a) The raw material is very rich for kaolin, yield of washing is 70%. Whiteness of washed kaolin is quite low - about 65%, abrasivity is suitable.

b) Whiteness of kaolinitic fraction can be increased by chemical bleaching up to 72%, by magnetic separation up to 70%, by delamination up to 68.6%. After upgrading the kaolin can be used as a paper filler.

c) Washed kaolin has suitable technological properties for utilization in ceramic industry in production of tiles, stoneware, sanitaryware, pottery, electrical and laboratory porcelain. Amount of by- product of washing is very low for the kaolin Maukmai. Sand is very fine-grained with a high content of colouring oxides. It can be used in a limited amount in building industry. Silty fraction contains only a small amount of Al_2O_3 and it can be used in ceramic industry as a component of body mixtures.

d) Following technology of upgrading is recommended for kaolin Maukmai:

- washing
- classification in hydrocyclones 150 mm (HYCY 150) for removing of fine-grained sand
- classification in hydrocyclones 50 mm (HYCY 50) for removing of silty fraction
- flocculation
- thickening
- filtration
- drying

5. YOEZAYAT

a) Yield of washing is about 65% for the raw material. Whiteness of kaolinitic fraction is low (60%) and abrasivity is high. Kaolinitic fraction contains quite low amount of kaolinite and relatively high concentration of quartz and feldspar. Kaolin cannot be recommended as a paper filler because of its low whiteness and high abrasivity.

b) Whiteness of the washed kaolin can be partly increased by magnetic separation (whiteness 64%), chemical bleaching (whiteness 63%) or delamination (whiteness 63%). The main area of application of the kaolin Yoezayat is ceramic industry, especially production of wall tiles, floor tiles, facade tiles, stoneware and pottery. Utilization of by-products of washing will be very problematic because of very low content of Al_2O_3 and a high concentration of impurities. Part of sandy fraction can be used in building industry.

c) The main area of application of the kaolin Yoezayat is ceramic industry, especially production of wall tiles, floor tiles, facade tiles, stoneware and pottery. Utilization of by-products of washing will be very problematic because of very low content of Al_2O_3 and a high concentration of impurities. Part of sandy fraction can be used in building industry.

d) Following technology of upgrading is recommended for kaolin Yoezayat:

   - washing
   - classification in hydrocyclones 150 mm (HYCY 150) for removing of fine-grained sand
   - classification in hydrocyclones 50 mm (HYCY 50) for removing of silty fraction
   - flocculation
   - thickening
   - filtration
   - drying

6. MARIZAN

a) Yield of washing of the raw material is below 20%, but the product has a good whiteness (71.8%) and suitable abrasivity (19 mg). Washed kaolin can be used as a medium quality filler in paper production.

b) Whiteness of the washed kaolin can be increased by magnetic separation to the value 7[illegible]%, by chemical bleaching to the value 77% and by delamination to the value 72.7%.

This kaolin is not very suitable for ceramic productions because of its low strength and colour after firing.

c) Sand as by- product of washing can be used for production of lower quality glasses, as a foundry sand and also in building industry.
Silty fraction of washing can be utilized in some ceramic productions as forexample floor tiles, wall tiles, stoneware and pottery.

d) Following technology of upgrading is recommended for kaolin Mabizan:

- washing
- separation of sand (for example by spiral classificators)
- classification in hydrocyclones 150 mm (HYCY 150) for removing of fine-grained sand
- classification in hydrocyclones 50 mm (HYCY 50) for removing of silty fraction
- flocculation
- sedimentation
- filtration
- drying

7. <u>KYAUKTAGA</u>

a) The raw material is a compact rock which has to be processed by crushing and grinding. Overgrinding can influence negatively the final whiteness of the kaolin product.

b) Kaolin has a high yield of kaolinitic fraction (15.2%). Washed kaolin has a good whiteness (71%), suitable abrasivity (19 and 28 mg) and it can be used as a good quality paper filler.

c) Whiteness of the washed kaolin can be improved by magnetic separation (76.5%) or chemical bleaching (49%). Delamination decreases the kaolin whiteness substantially.

d) By-products of washing (sand and silty fraction) have a similar chemical composition and they can be utilized in a limited amount in ceramic industry.

e) Following technology of upgrading is recommended for kaolin Kyauktaga:

- crushing
- grinding
- classification of sand and removing of sandy fraction
- classification in hydrocyclones 150 mm (HYCY 150) for removing of fine-grained sand
- classification in hydrocyclones 50 mm (HYCY 50) for removing of silty fraction
- flocculation
- sedimentation
- filtration
- drying

III. TECHNOLOGICAL TESTS

1. METHODS APPLIED

The samples of delivered raw materials were at first evaluated in a macroscopic way from the point of view of mineralogy and petrography. Further they were analyzed chemically by the methods of classical wet analysis (by gravimetric, titrimetric and photometric methods), combined with the method of absorption spectrophotometry. Mineralogical analyses were executed by the X-ray method and by the thermal methods.

Thermal analyses, i. e. differential and gravimetric thermal analyses, were carried out by means of derivatographic method (Q - 1500 D, MOM, Hungary). Particle size distribution of silty fraction and clay fraction were determined by sedimentometric method (Sedigraph 5000, Micromeritics). Abrasivity of the kaolinitic fraction was ascertained by the apparatus Einlehner AT 1000. The device Opton Elrepho RFA 2 was used for measurement of brightness.

Laboratory washing was carried out with 0.5 kg of the kaolin sample, pilot washing was carried out with 25 kg of the raw material. During the laboratory washing, a sandy fraction was separated with the sieve 0.063 mm; silty fraction and kaolinitic fraction were separated by sedimentation.

Hydrocyclones 50 mm (HYCY 50) were used for classification and separation of silty and kaolinitic fractions.

Conditions of classification in HYCY 50:

- concentration of dry material in inlet suspension 90 - 110 g/l

  (for Mabizan only 50 g/l because of the high content of sandy fraction)
- pressure used 0.4 MPa
- outflow nozzle diameter 3.2 mm
- overflow nozzle diameter 11 mm

Overflow from HYCY was controlled with the sieve 0.063 mm.

Viscosity was measured by a flow viscosimeter. Litre weight of the suspension was 1445 g/l and soda ash was used for dispergation in the amount of 0.15%.

Tests of high intensity magnetic separation were carried outwith a pilot separator SALA 10-15-20. Following conditions of separation were used:

- concentration of dry material in suspension 300 g/l
- dispergation 0.6% of sodium hexamethaphosphate
- mixing of suspension before separation 5 minutes
- diameter of fibres in matrix 50 microns
- loading of matrix $1.8\ g\ .\ cm^{-3}$
- flow rate $6\ mm\ .\ s^{-1}$
- magnetic induction 1.1 T and 1.9 T

Standard method of chemical bleaching was used for all samples. There are three basic technological steps in this method:

a) to convert colouring admixtures into a colourless form
b) to fix the colourless form
c) to adjust filterability of kaolin and to stabilize whiteness

Characterization of chemical bleaching process:

a) discontinuous course
b) time of one bleaching cycle - approx. 2 hours
c) concentration of kaolin suspension used for bleaching - 15%
d) no ecologically dangerous waste
e) energy consumption for 1 ton of kaolin - 25 kWh

Glass balls of different diameterswere used for grinding during delamination.

2. Testing of Burmese Kaolins for Use as Paper Filler

2.1. SHWE DAUNG

a) Raw Material Characterization

Moisture (% H_2O)		2.05
Chemical analysis (%)	Al_2O_3	25.39
	Na_2O	0.17
	K_2O	1.35

Mineralogical Characterization

White-grey, fine, as far as very fine-grained, completely desintegrated raw material with a low level of consolidation. Besides prevailing clay minerals, the raw material contains small amount of relatively bigger quartz grains, small plates of light mica and a small amount of turmaline and iron hydroxides.

Quartz is a prevailing mineral in the residues on the sieve 0.063 mm. Feldspar, muscovite and turmaline are also present in small amounts. Biotite and iron oxides and hydroxides are present as accessories.

The sample contains from 50 to 55% of kaolinite, 35 - 40% of quartz and 10% of feldspar (especially potassium feldspar). Content of micas is very low.

b) Laboratory Washing

Balance of washing		Yield (wt %)
Sandy fraction	- above 0.063 mm	36.4
Silty fraction	- 0.063 - 0.02 mm	34.5
Kaolinitic fraction	- below 0.02 mm	29.1

Properties of Laboratory Washing Products:

Chemical Analysis (%):

	Sandy fraction	Silty fraction	Kaolinitic fraction
L.O.I.	2.35	8.84	11.91
SiO_2	85.35	62.50	51.57
TiO_2	0.22	0.30	0.46
Al_2O_3	9.28	26.74	32.31
Fe_2O_3	1.04	1.06	1.61
MgO	0.11	0.14	0.29
CaO	0.040	0.12	0.65
Na_2O	0.25	0.16	0.11
K_2O	1.36	0.14	1.09

Mineralogical Analysis (%):

Kaolinite	15	65	85
Quartz	70	35	10
Feldspar	5-10	< 1	< 5
Micas	< 5		< 5

Technological Properties of Kaolinitic Fraction (below 0.02 mm):

Whiteness (%)	53.2
Abrasivity (Mg)	22.-

Properties of Sandy Fraction (above 0.063 mm):

The fraction is formed by fine-grained sand of yellowish colour, which contains high amount of impurities, especially micas and organic admixtures.

Grain Size Distribution of Sandy Fraction:

Fraction (mm)	Content (wt %)	Total (wt. %)
+1.0	10.8	10.8
0.8 - 1.0	3.4	14.2
0.6 - 0.8	4.8	19.0
0.4 - 0.6	10.4	29.4
0.3 - 0.4	5.8	35.2
0.2 - 0.3	12.8	48.0
0.1 - 0.2	26.2	74.2
-0.1	25.8	100.-
Washable matters (%)		1.63
Medium diameter of grain (mm)		0.14

c) Pilot Washing

Balance	Yield (wt %)
Sand - above 0.3 mm	32.6
Outflow HYCY 50	35.9
Overflow HYCY 50	31.5

Properties of Overflow HYCY 50, kaolinitic fraction - below 0.02 mm:

Whiteness (%)	53.3
Abrasivity (mg)	13.0
Strength of casted body (MPa)	1.94
Viscosity (S)	10.0
Shrinkage after drying (%)	9.6
Shrinkage after firing (%)	12.6
Total shrinkage (%)	21.0
Colour after firing	light yellow
Forming of body (mm . $min^{-1/2}$)	1.25

Grain Size Distribution:	content (wt %)
Fraction (microns)	
20 - 60	1
10 - 20	4
5 - 10	20
2 - 5	30
1 - 2	15
-1	30

Chemical Analysis:	content (wt %)
Fe_2O_3	1.56
TiO_2	0.47

Possibilities of Treatment of Overflow HYCY 50:

1) Magnetic separation:

magnetic field intensity (T)	Sample	Yield (wt %)	Content of Fe_2O_3 (wt %)	TiO_2 (wt %)	whiteness (%)
	inlet		1.56	0.74	53.3
1.1	P O M	94.4 0.4 5.2	1.23	0.42	58.9
1.9	P O M	89.2 4.4 6.4	1.19	0.36	59.4

P - non-magnetic product; O - non-magnetic by-product; M - magnetic product

2. Chemical bleaching:

	Whiteness (%)
Inlet (before bleaching)	54.0
Product (after bleaching)	64.9

Different methods of chemical bleaching were tested. The maximum value of whiteness reached with the kaolin Shwe Daung was 69.2%, it means increasing of whiteness about 15.2%.

3) Delamination

	Whiteness (%)
Inlet	54.0
Product	59.7

2.2. WELLAN

a) Raw Material Characterization

Moisture (% H_2O)		5.8
Chemical Analysis(%)	Al_2O_3	19.61
	Na_2O	0.11
	K_2O	1.79

Mineralogical Characterization

White-grey, uniformly fine-grained raw material with a low consolidation and a high content of quartz grains.

Quartz is a prevailing mineral in the residues on the sieve 0.063 mm and it forms about 85% of the residues. Muscovite is present in the amount about 10%. Feldspar was also proved in a small amount about 5%. Biotite and iron hydroxides are present as accessories.

Content of kaolinite in the sample is from 40 to 45%. Quartz is present in a similar amount. Feldspars and micas are proved in the concentrations from 5 to 10%.

b) Laboratory Washing

Balance of washing	yield (wt %)
Sandy fraction - above 0.063 mm	48.4
Silty fraction - 0.063 - 0.02 mm	18.6
Kaolinitic fraction - below 0.02 mm	33.0

Properties of Laboratory Washing Products:

	Sandy fraction	Silky fraction	Kaolinitic fraction
L.O.I.	1.21	6.68	12.25
SiO_2	91.78	66.58	49.72
TiO_2	0.36	0.97	1.10
Al_2O_3	4.37	21.68	33.54
Fe_2O_3	0.32	0.88	1.11
MgO	0.039	0.21	0.29
CaO	0.043	0.12	0.68
Na_2O	0.11	0.14	0.090
K_2O	1.77	2.74	1.22

Mineralogical Analysis (%):

Kaolinite	5 - 10	40	80
Quartz	85	45	15
Feldspar	10	15	5

Technological Properties of Kaolinitic Fraction (below 0.02 mm):

Whiteness (%)	67.1
Abrasivity (mg)	24.5

Properties of Sandy Fraction (above 0.063 mm):

The fraction is formed by fine-grained, grey-white sand. Ochre and black grains of impurities and organic admixtures are present in coarser fractions. Fine-grained mica represents the main impurity of the fraction.

Grain Size Distribution of Sandy Fraction:

Fraction (mm)	Content (wt %)	Total (wt %)
+ 1.0	0.4	0.4
0.8 - 1.0	0.1	0.5
0.6 - 0.8	0.1	0.6
0.4 - 0.6	0.4	1.0
0.3 - 0.4	0.8	1.8
0.2 - 0.3	12.8	14.6
0.1 - 0.2	57.0	71.6
- 0.1	28.4	100.-
Washable matters (%)		1.72
Medium diameter of grain (mm)		0.14

c) Pilot Washing:

Balance	Yield (wt %)
Sand - above 0.3 mm	22.3
Outflow HYCY 50	40.3
Overflow HYCY 50	37.4

Properties of Overflow HYCY 50 (kaolinitic fraction - below 0.02 mm):

Whiteness (%)	63.5
Abrasivity (mg)	19.-
Strength of casted body (MPa)	1.01
Viscosity (s)	40.8

Shrinkage after drying (%)	8.4
Shrinkage after firing (%)	+ 4.8 (1410 °C)
Total shrinkage (%)	22.0
Colour after firing	light yellow
Forming of body ($mm \cdot min.^{-1/2}$)	1.23

Grain Size Distribution:

Fraction (microns)	Content (wt %)
20 - 60	0
10 - 20	0
5 - 10	18
2 - 5	32
1 - 2	20
below 1	30

Chemical Analysis:	Content (wt %)
Fe_2O_3	1.27
TiO_2	1.15

Possibilities of Treatment of Overflow HYCY 50:

1) Magnetic Separation

Magnetic field intensity (T)	Sample	Yield (wt %)	Content of Fe_2O_3 (wt %)	Content of TiO_2 (wt %)	Whiteness (%)
	inlet	100	1.27	1.15	63.5
1.1	P	94.2	1.01	0.88	68.5
	O	0.8			
	M	5.0			
1.9	P	92.4	0.99	0.89	69.8
	O	1.5			
	M	6.1			

P - non-magnetic product; O - non-magnetic by-product; M - magnetic product

2) Chemical Bleaching:	Whiteness (%)
Inlet (before bleaching)	63.8
Product (after bleaching)	72.5

3) Delamination:	Whiteness (%)
Inlet	63.8
Product	66.0

2.3. KADATDAUK

a) Raw Material Characterization

Moisture (% H_2O)		2.3
Chemical Analysis (%)	Al_2O_3	22.42
	Na_2O	0.18
	K_2O	1.48

Mineralogical Characterization

Light grey kaolin with small brown and red-brown dots and spots. It is fine-grained with a low level of consolidation and irregular disintegration. The raw material is nearly completely weathered and it contains many pores and small caverns.

Residues on the sieve 0.063 mm are formed mainly by quartz (90%) which was proved in the whole grain size spectrum. Feldspar and iron oxides and hydroxides are present in the amounts about 5%. Muscovite is present only as accessory in a very small amount.

Quartz is mostly angular, turbid as far as semi-bright. The concentration of quartz is 45% in the sample, content of kaolinite is approximately 45 - 50%. Feldspars and micas were proved in the concentrations about 5%.

b) Laboratory Washing

Balance	Yield (wt %)
Sandy fraction - above 0.063 mm	43.3
Silty fraction - 0.063 - 0.02 mm	21.3
Kaolinitic fraction - below 0.02 mm	35.4

Properties of Laboratory Washing Products:

Chemical Analysis (%):

	Sandy fraction	Silty fraction	Kaolinitic fraction
L.O.I.	1.11	6.71	11.78
SiO_2	92.75	67.44	50.12
TiO_2	0.19	1.28	1.09
Al_2O_3	3.77	20.26	32.83
Fe_2O_3	1.27	1.37	1.72
MgO	0.036	0.24	0.38
CaO	0.029	0.11	0.59
Na_2O	0.051	0.13	0.099
K_2O	0.79	2.46	1.39

Mineralogical Analysis (%):

Kaolinite	< 5	40	80
Quartz	85 - 90	50	< 5
Mica	< 5	5	5
Feldspar	< 5	5 - 10	5 - 10

Technological Properties of Kaolinitic Fraction (below 0.02 mm):

Whiteness (%)	58.9
Abrasivity (mg)	15.-

Properties of Sandy Fraction (above 0.063 mm):

Sand is fine-grained and yellowish. It contains small amounts of conglomerated quartz grains, organic admixtures and fine-grained white mica.

Grain Size Distribution of Sandy Fraction:

Fraction (mm)	Content (wt %)	Total (wt %)
+ 1.0	13.2	13.2
0.8 - 1.0	3.4	16.6
0.6 - 0.8	4.8	21.4
0.4 - 0.6	11.6	33.-
0.3 - 0.4	6.2	39.2
0.2 - 0.3	16.2	55.4
0.1 - 0.2	25.8	81.2
- 0.1	18.8	100.-
Washable matters (%)		2.62
Medium diameter of grain (mm)		0.22

c) Pilot Washing

Balance	Yield (wt %)
Sand - above 0.3 mm	48.6
Outflow HYCY 50	15.2
Overflow HYCY 50	36.2

Properties of Overflow HYCY 50 (kaolinitic fraction-below 0.02 mm):

Whiteness (%)	53.4	
Abrasivity (mg)	12.-	
Strength of casted body (MPa)	0.88	
Shrinkage after drying (%)	6.8	
Shrinkage after firing (%)	12.5	(1410°C)
Total shrinkage (%)	18.8	
Colour after firing	medium grey, small smelted spots on the edges of testing specimen	

Grain Size Distribution: Fraction (microns)	Content (wt %)
20 - 60	0
10 - 20	2
5 - 10	6
2 - 5	10
1 - 2	10
below 1	72

Chemical Analysis:	Content (wt %)
Fe_2O_3	1.81
TiO_2	1.10

Possibilities of treatment of Overflow HYCY 50:

1. Magnetic Separation

magnetic field intensity (T)	Sample	Yield (wt. %)	Content of Fe_2O_3 (wt. %)	Content of TiO_2 (wt. %)	whiteness (%)
	inlet		1.81	1.10	53.4
1.1	P O M	88.2 2.1 9.7	1.73	0.95	59.2
1.9	P O M	88.1 1.5 10.4	1.74	0.98	59.5

P - non-magnetic product; O - non-magnetic by-product; M - mag. product

2. Chemical Bleaching

	Whiteness (%)
Inlet (before bleaching)	56.0
Product (after bleaching)	63.2

3) Delamination:

	Whiteness (%)
Inlet	53.7
Product	56.0

2.4. MAUKMAI

a) Raw Material Characterization

Moisture ($\%H_2O$)		5.8
Chemical analysis (%)	Al_2O_3	19.61
	Na_2O	0.81
	K_2O	1.79

Mineralogical Characterization

Kaolin is nearly white, very fine-grained with a low level of consolidation. It is completely weathered and it has a high content of clay minerals.

Quartz is a prevailing mineral in the residues on the sieve 0.063 mm. Muscovite in a small amount was also proved. Feldspar, muscovite and iron hydroxides are present as accessories.

Comparing with other samples, kaolin MAUKMAI has the highest content of kaolinite (about 60%). Quartz was proved in the amount from 25 to 30%, mica from 5 to 10% and feldspar about 5%.

b) Laboratory Washing

Balance of washing	Yield (wt. %)
Sandy fraction - above 0.063 mm	4.9
Silty fraction - 0.063 - 0.02 mm	27.2
Kaolinitic fraction - below 0.02 mm	67.9

Properties of Laboratory Washing Products:

Chemical Analysis (%):

	Sandy fraction	Silty fraction	Kaolinitic fraction
L.O.I.	1.07	4.10	11.31
SiO_2	90.79	75.56	51.91
TiO_2	0.41	0.79	0.83
Al_2O_3	4.86	15.38	32.69
Fe_2O_3	0.34	0.62	1.03
MgO	0.073	0.13	0.29
CaO	0.16	0.18	0.58
Na_2O	0.48	0.72	0.22
K_2O	1.82	2.52	1.14

Mineralogical Analysis (%):

Kaolinite	5	30	80
Quartz	80 - 85	60	10
Mica	5 - 10	5	< 5
Feldspar	< 5	5	5

Technological Properties of Kaolinitic Fraction (below 0.02 mm):

Whiteness (%)	65.6
Abrasivity (mg)	30.-

Properties of Sandy Fraction (above 0.063 mm):

Screen oversize fraction (above 0.063 mm) is formed especially by very fine-grained quartz. The sample contains also a big amount of white mica and organic admixtures.

Grain Size Distribution of Sandy Fraction:

Fraction (mm)	Content (wt. %)	Total (wt. %)
+ 1.0	0.06	0.06
0.8 - 1.0	0.03	0.09
0.6 - 0.8	0.03	0.12
0.4 - 0.6	0.6	0.72
0.3 - 0.4	0.9	1.62
0.2 - 0.3	3.9	5.52
0.1 - 0.2	22.0	27.52
below 0.1	72.48	100.-
Washable matters (%)	not determined (very fine-grained sand)	
Medium diameter of grain (mm)		0.09

c) Pilot Washing

Balance	Yield (wt. %)
Sand - above 0.3 mm	4.2
Outflow HYCY 50	25.0
Overflow HYCY 50	70.8

Properties of Overflow HYCY 50 (kaolinitic fraction - below 0.2 mm):

Whiteness (%)	64.8
Abrasivity (mg)	19.-
Strength of casted body (MPa)	1.57
Shrinkage after drying (%)	6.4
Shrinkage after firing (%)	11.5 (1410°C)
Total shrinkage (%)	17.2
Colour after firing	light yellow
Viscosity (s)	6.9
Forming of body (mm . min$^{-1/2}$)	0.54

Grain Size Distribution:

Fraction (microns)	Content (wt. %)
20 - 60	0
10 - 20	3
5 - 100	30
2 - 5	30
1 - 2	17
below 1	20

Chemical Analysis:

Fe_2O_3	1.0
TiO_2	0.79

Possibilities of Treatment of Overflow HYCY 50:

1) Magnetic Separation

Magnetic field intensity (T)	Sample	Yield (wt.%)	Content of Fe_2O_3 (wt. %)	Content of TiO_2 (wt. %)	Whiteness (%)
	inlet		1.00	0.79	64.8
1.1	P	91.9	0.88	0.64	69.9
	O	4.7			
	M	3.4			
1.9	P	93.2	0.87	0.62	71.2
	O	2.1			
	M	4.7			

P - non-magnetic product O - non-magnetic by-product M - magnetic product

2) Chemical Bleaching:

	Whiteness (%)
Inlet (before bleaching)	65.3
Product (after bleaching)	72.1

3) Delamination:

	Whiteness (%)
Inlet	65.3
Product	68.6

2.5. YOEZAYAT

a) Raw Material Characterization

Moisture (% H_2O)		1.8
Chemical analysis (%)	Al_2O_3	21.96
	Na_2O	0.41
	K_2O	2.53

Mineralogical Characterization

Kaolin YOEZAYAT is white-grey, very fine-grained, with a low level of consolidation, completely weathered.

Quartz is a prevailing mineral in residue on the sieve 0.063 mm (about 95%). Muscovite and feldspar are also present in a small amount. Biotite and iron oxides and hydroxides were proved only in accessoric amounts.

Content of kaolinite is 40% in the raw material, concentration of quartz is from 35 to 40%, micas from 15 to 20% and feldspar about 5%.

b) Laboratory Washing

Balance of washing	Yield (wt. %)
Sandy fraction - above 0.063 mm	5.5
Silty fraction - 0.063 - 0.02 mm	26.7
Kaolinitic fraction - below 0.02 mm	67.8

Properties of Laboratory Washing Products:

Chemical Analysis (%):

	Sandy fraction	Silty fraction	Kaolinitic fraction
L.O.I.	1.48	3.78	3.02
SiO_2	88.33	78.03	58.58
TiO_2	0.29	0.76	1.06
Al_2O_3	5.22	11.51	25.86
Fe_2O_3	1.02	1.89	2.00
MgO	0.42	1.04	0.91
CaO	0.97	0.85	0.65
Na_2O	0.79	0.50	0.23
K_2O	1.48	1.64	2.69

Mineralogical Analysis (%):

Kaolinite	< 5	25	60
Smectite	< 5	10	10
Quartz	90	60	20
Feldspar	< 5	< 5	10
Chlorite		?	?

Technological Properties of Kaolinitic Fraction (below 0.02 mm):

Whiteness (%)	60.4
Abrasivity (mg)	72.-

Properites of Sandy Fraction (above 0.063 mm):

The fraction is formed by very fine-grained quartz. Organic admixtures and fine-grained micas are also present. The sand also contains a small amount of white and grey grains with the size above 1 mm. The grains have a low strength.

Grain Size Distribution of Sandy Fraction:

Fraction (mm)	Content (wt.%)	Total (wt. %)
+ 1.0	1.2	2.2
0.8 - 1.0	0.2	2.4
0.6 - 0.8	0.4	2.8
0.4 - 0.6	2.4	5.2
0.3 - 0.4	2.2	7.4
0.2 - 0.3	5.0	12.4
0.1 - 0.2	34.6	47.0
below 0.1	53.0	100.-
Washable matters were not determined - fine-grained sand		
Medium size of grain (mm)		0.10

c) Pilot Washing

Balance	Yield (wt. %)
Sand - above 0.3 mm	1.5
Outflow HYCY 50	31.9
Overflow HYCY 50	66.6

Properties of Overflow HYCY 50 (kaolinitic fraction - below 0.02 mm):

Whiteness (%)	58.8
Abrasivity (mg)	31.-
Strength of casted body (MPa)	2.74
Viscosity (s)	7.1
Shrinkage after drying (%)	10.4
Shrinkage after firing (%)	6.25 (1410°C)
Total shrinkage (%)	16.0
Colour after firing	light yellow-brown
Forming of body (mm . $min^{-1/2}$)	0.54

Grain Size Distribution:

Fraction (microns)	Content (wt. %)
20 - 60	0
10 - 20	4
5 - 10	11
2 - 5	27
1 - 2	15
below 1	43

Chemical Analysis:	Content (wt. %)
Fe_2O_3	2.09
TiO_2	1.17

Possibilities of Treatment of Overflow HYCY 50:

1) Magnetic Separation:

Magnetic field intensity (T)	Sample	Yield (wt.%)	Content of Fe_2O_3 (wt. %)	Content of TiO_2 (wt. %)	Whiteness (%)
	inlet	100.-	2.09	1.17	58.8
1.1	P O M	88.7 4.5 6.8	1.63	0.93	64.5
1.9	P O M	84.8 4.2 11.0	1.60	0.93	63.8

P - non-magnetic product O - non-magnetic by-product M - magn. product

2) Chemical Bleaching: Whiteness (%)

Inlet (before bleaching)	59.8
Product (after bleaching)	62.8

3) Delamination: Whiteness (%)

Inlet	59.8
Product	62.6

2.6. MABIZAN

a) Raw Material Characterization

Moisture (% H_2O)		9.4
Chemical Analysis (%)	Al_2O_3	10.04
	Na_2O	0.085
	K_2O	0.38

Mineralogical Characterization

White-grey, fine-grained as far as medium grained kaolin with a low level of consolidation and admixtures of colouring oxides. High content of fine-grained quartz and a low content of clay minerals are the typical properties of the raw material.

Quartz forms about 95% of the residue on the sieve 0.063 mm. 5% of residue is formed by feldspar. Iron oxides and hydroxides are present as accessories. Colour of quartz is light grey, grains are usually slightly turbid and semi-bright.

The total content of quartz in the sample is 60 - 65%, kaolinite forms only from 25 to 30%. Micas and feldspar were proved in the concentration about 5%.

b) Laboratory Washing

Balance of washing	Yield (wt. %)
Sandy fraction - above 0.063 mm	71.6
Silty fraction - 0.063 - 0.02 mm	8.7
Kaolinitic fraction - below 0.02 mm	19.7

Properties of Laboratory Washing Products:

Chemical Analysis (%):

	Sandy fraction	Silty fraction	Kaolinitic fraction
L.O.I.	0.41	0.85	11.58
SiO_2	98.41	70.31	53.94
TiO_2	0.14	0.82	0.54
Al_2O_3	0.82	19.49	30.23
Fe_2O_3	0.11	1.23	1.83
MgO	0.017	0.23	0.33
CaO	0.010	0.077	0.083
K_2O	0.063	0.91	0.92

Mineralogical Analysis (%):

Kaolinite	< 5	40	90 - 95
Smectite			
Feldspar		5	< 5
Quartz	> 95	60	< 5

Technological Properties of Kaolinitic Fraction (below 0.02 mm):

Whiteness (%)	71.8
Abrasivity (mg)	37.-

Properties of Sandy Fraction (above 0.063 mm):

Sand is white-grey, medium fine-grained. Bigger grains are white as far as grey-white, seldom pink or ochre without organic admixtures. White fine-grained mica is present in accessoric amount. Comparing with other samples of kaolins, sandy fraction of kaolin Mabizan is the best quality one. It can be used in glass production.

Grain Size Distribution of Sandy Fraction:

Fraction (mm)	Content (wt. %)	Total (wt. %)
+ 1.0	1.0	1.0
0.8 - 1.0	0.6	1.6
0.6 - 0.8	2.2	3.8
0.4 - 0.6	28.2	32.0
0.3 - 0.4	28.2	60.2
0.2 - 0.3	29.4	89.6
0.1 - 0.2	7.2	96.8
below 0.1	3.2	100.0
Washable matters (%)		0.22
Medium diameter of grain (mm)		0.35

c) Pilot Washing

Balance	Yield (wt. %)
Sand - above 0.3 mm	71.6
Outflow HYCY 50	11.8
Overflow HYCY 50	16.6

Properties of Overflow (kaolinitic fraction - below 0.02 mm):

Whiteness (%)	70.9	
Abrasivity (mg)	19.-	
Strength of casted body (MPa)	0.49	
Shrinkage after drying (%)	8.0	
Shrinkage after firing (%)	14.4	(1410 ^{o}C)
Total shrinkage (%)	21.6	
Colour after firing	light yellow, grey-brown smelted spots on a lower side of testing specimen	

Grain Size Distribution:

Fraction (microns)	Content (wt. %)
20 - 60	0
10 - 20	3
5 - 10	12
2 - 5	48
1 - 2	30
below 1	7

Possibilities of Treatment of Overflow HYCY 50:

1) Magnetic Separation:

magnetic field intensity (T)	Sample	Yield (wt.%)	Content of Fe_2O_3 (wt. %)	Content of TiO_2 (wt. %)	Whiteness (%)
	inlet	100.-	1.89	0.66	70.9
1.1	P O M	94.5 2.2 4.3	1.88	0.56	73.2
1.9	P O M	88.4 6.3 5.3	1.87	0.58	72.8

P - non-magnetic product O - non-magnetic by-product M - magnetic product

2) <u>Chemical Bleaching:</u>	Whiteness (%)
Inlet (before bleaching)	70.1
Product (after bleaching)	77.2

3) <u>Delamination:</u>	Whiteness (%)
Inlet	70.1
Product	72.7

2.7. KYAUKTAGA

a) Raw Material Characterization

Chemical Analysis (%)	Al_2O_3	23.75
	Na_2O	0.104
	K_2O	0.56

Mineralogical Characterization

Volcanic rock of white-grey colour and low level of kaolinitisation. The raw material is fine as far as medium-grained, consolidated and irregularly friable. White, clayey pseudomorphoses after medium size feldspar grains are visible on some parts of the rock. Bigger grains of cristoballite are present quite rarely. Fine plates of light mica are present in accessoric amount.

Residues on the sieve 0.063 mm are formed especially by the grains of original unwashed rock. Feldspar, cristobalite, muscovite, iron oxides and hydroxides are present only in small amounts.

Feldspar is a predominant mineral in a silty fraction, muscovite, iron oxides and hydroxides are present in small amounts.

Kaolinite is predominant mineral in the sample (about 60%), cristobalite forms from 20 to 25%. Feldspars, micas and [illegible]lite are present in a total concentration from 15 to 20%.

b) Laboratory Tests

The raw material was crushed in a jaw crusher and ground in a porcelain jar mill for 24 hours.

Grinding conditions:

weight ratio - grinding porcelain elements : water : raw material = 1 : 1 : 1

Balance of washing	Yield (wt. %)
Sandy fraction - above 0.063 mm	38.2
Silty fraction - 0.063 - 0.02 mm	16.6
Kaolinitic fraction - below 0.02 mm	45.2

Properties of Laboratory Washing Products:

Chemical Analysis (%):

	Sandy fraction	Silty fraction	Kaolinitic fraction
L.O.I.	9.94	8.82	10.61
SiO_2	63.17	63.76	60.64
TiO_2	0.70	0.96	1.00
Al_2O_3	22.11	20.84	25.21
Fe_2O_3	3.71	5.23	1.95
MgO	0.042	0.064	0.050
CaO	0.067	0.088	0.38
Na_2O	0.087	0.11	0.06[illegible]
K_2O	0.17	0.13	0.101

Mineralogical Analysis (%):

Kaolinite	[illegible]	[illegible]	60
Cristobalite	10	10	35 - 40
Non-oxides and hydroxides, micas	< [illegible]	[illegible]	< 3

Technological Properties of Kaolinitic Fraction (below 0.02 mm):

Whiteness (%)	65.0
Abrasivity (mg)	28

c) Pilot Test

The raw material was upgraded by crushing in jaw crusher and ground in a ball mill. Grinding conditions were determined experimentally according to the residues on the sieve 0.063 mm.

Sample for pilot washing was ground in the ball mill at following conditions:

Weight ratio raw material : water : grinding elements = 1 : 1.5 : 1

grinding time - 4 hours

Pilot Washing

Balance	Yield (wt. %)
Sand - above 0.3 mm	9.0
Outflow HYCY 50	45.3
Overflow HYCY 50	45.7

Properties of Overflow HYCY 50 (kaolinitic fraction - below 0.02 mm):

Whiteness (%)	71.3
Abrasivity (mg)	19.-
Strength of casted body (MPa)	0.434
Shrinkage after drying (%)	7.0
Shrinkage after firing (%)	18.7 (1410°C)
Total shrinkage	24.4
Colour after firing	light yellow, upper edges of testing specimen are grey

Grain Size Distribution:

Fraction (microns)	Content (wt. %)
20 - 60	0
10 - 20	7
5 - 10	16
2 - 5	18
1 - 2	10
below 1	49

Chemical Analysis:	Content (wt.%)
Fe_2O_3	0.94
TiO_2	0.84

Possibilities of Treatment of Overflow HYCY 50:

1) Magnetic Separation:

Magnetic field intensity (T)	Sample	Yield (wt.%)	Content of Fe_2O_3 (wt.%)	Content of TiO_2 (wt. %)	Whiteness (%)
	inlet	100.-	0.94	0.84	71.3
1.1	P O M	93.7 2.8 3.5	0.52	0.77	76.5
1.9	P O M	92.6 2.7 4.7	0.50	0.62	76.8

P - non-magnetic product O - non-magnetic by-product M - magnetic product

2) Chemical Bleaching:

	Whiteness (%)
Inlet (before bleaching)	71.4
Product (after bleaching)	79.2

3) Delamination:	Whiteness (%)
Inlet	71.0
Product	60.9

IV. FINAL NOTE

The kaolins from Burma were tested from the point of view of their suitability for paper making. Testing of suitable upgrading methods for an increasing of whiteness was the principal objective of the tests conducted.

The tests carried out issued in the conclusion that the kaolins Shwe Daung, Wellan, Kadatdauk, Maukmai and Yoezayat are not suitable for paper making without upgrading. The usable clay fractions have low whiteness and therefore the possibilities of improvings the whiteness were verified by a high-gradient magnetic separation, chemical bleaching and delamination. Significant improving of properties was reached especially by chemical bleaching and magnetic separation.

Washed kaolins Mabizan and Kyauktaga have a sufficient whiteness (about 71%) and they can be used as paper fillers without upgrading.

All the kaolins tested can be used in various branches of ceramic industry. By-products of washing can be utilized in foundries (sand) and in ceramic industry (silty fraction).

UNIDO-Czechoslovakia Joint Programme, Non-metallic Industries, Pilsen and Research Institute for Ceramics, Refractories and Non-metallic Raw Materials, Pilsen, are ready to extend any further technical assistance in the areas of ceramics, refractories, [illegible] materials and non-metallic raw materials.

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Training Programme

Training programme of the mission was fulfilled during installation and production tests of the pilot mobile hydro-cyclone clay cleaning unit. Staff of the factory Paint No. 1 was acquainted with the principles, design, installation and operation of the unit. Basic principles of maintenance and repairs were also explained. The experts gave attention to the training and technical discussions with the technicians and laboratory staff of the factory. Main methods of kaolin upgrading, classification and testing were explained, discussed and demonstrated during several meetings. 10 workers and 15 technicians participated in the training programme and all of them were acquainted with operation, regulation and maintenance of the unit.

The experts organized also Technical Seminar for managers and specialists of Myanma Paper and Chemical Industries Corporation and Ceramic Industries Corporation. The following three lectures were presented:

a) Activities of the UNIDO-Czechoslovakia Joint Programme, Non-metallic Industries, Pilsen
b) Kaolin and Its Utilization
c) Methods of Kaolin Up-grading and Beneficiation

30 technicians and specialists took part in the seminar which was completed by the technical discussions dealing with the specific problems of production and utilization of kaolin in the paper industry, utilization and processing of the feldspar sands and many others.

List of technicians of Paint Factory No. 1 participating in the Training Programme:

Mr U Khin Nyo	- Factory Manager
Mr. U Win Aung	- Deputy Assistant Director
Mr. U Tin Co	- Assistant Factory Manager
Ms. Daw Khin Swe Win	- Head of Production Department
Ms. Daw Maw Maw Aye	- Head of Quality Control Dept.
Mr. U Sein Han	- Head of Department
Mr. U Min That Pe	- Head of Financial Department
Ms. Daw Cho Cho	- Production Engineer
Ms. Daw Khin Khin Aye	- Chemical Engineer - Quality Control
Mr. U Mg Mg Lay	- Assistant Manager (Planning)
Mr. U Bala Sein	- Maintenance Engineer
Mr. U Sit Hlaing	- Maintenance Engineer