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POLICY OF JSC "APATIT" IN IMPROVING ITS APATITE CONCENTRATE FOR CONSUMERS' NEEDS[1]

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During the conversion from the obsolete methods of managing a company in the former USSR to the market base under modern condition, a clear understanding of customers’ interests, internal resources and interdependent strategic concepts, that will help to reach a set strategic goal becomes the primary objective of JSC Apatit’s management. The principal goal of JSC Apatit is to increase net profit growth, improve quality and broaden our range of products, to extend the share of service and attendant services as well as enhance the prestige of the company. Following this basic purpose, the marketing aims of JSC Apatit can be shaped as follows: increasing sales, reducing production costs, and entering new markets.

Being one of the world’s largest phosphate rock sources, Joint Stock Company Apatit accounts for more than 80% of domestic phosphate rock supply and meets about 20% of overseas markets’ demand in phosphate rock grades containing more than 35,5% P_2O_5 (over 78% BPL).

The Apatit company was established in 1929. It is situated in the center of the Kola peninsula by the foot of the Khibiny mountains in the Kirovsko-Apatitsky industrial area. Within the core area are the towns of Kirovsk and Apatity which are connected to a non-freezing commercial sea port of Murmansk by a 200 km electrified railway (Figure 1).

The joint stock company carries out mining and processing of the apatite-nepheline ores of the Khibiny mountains deposits. 10 deposits containing 3856,4 million t of the ore reserves have been prospected within boundaries of the Khibiny mountains. Only five deposits are currently being exploited, their industrial ore reserves are 2400 million t (with P_2O_5 at 12 to 16%) can provide a stable Apatit’s operation for a sufficiently long period of time at annual apatite concentrate output of 10-15 million t.

JSC Apatit operates 4 mines (2 underground units and 2 open-pits), two dressing factories and over 20 auxiliary divisions ensuring smooth operation of motor and railway conveyances, water and power supply, spare parts manufacture and maintenance of machinery, buildings and constructions. The company’s staff totals some 15 thousand employees.

The basic product of the company is apatite concentrate known by this name to all domestic consumers and as Kola Apatite to overseas firms. The apatite concentrate is extracted by a flotation method from the crushed apatite-nepheline ore. After production of the apatite concentrate a number of products are extracted in the course of intensified processing of the tailings, the major of which is nepheline concentrate widely used in industry. Since 1929, during the entire period of the company’s operation about 1,5 billion t of the ore have been mined and processed, over 520 million t of the apatite concentrate and about 60 million t of the nepheline concentrate have been produced including 25 million t of the ore, 8,2 million t of the apatite concentrate and 0.9 million t of the nepheline concentrate in 1997.

The 1997 production level was conditioned by demand and the capacity use rate amounted to 86% for the ore, about 87% and 63% for the apatite and nepheline concentrates respectively. These figures testify that there are alternate capacities for a rise in output and sales. The company’s sales in 1997 totaled some Rb 2 trillion (USD 330 million) (Figure 2).

For a long period, JSC Apatit has been producing and delivering the apatite concentrate to domestic and overseas markets in accordance with the requirements of the Technical Conditions and then GOST-22275-90 (State Technical Specification), last edition of 1 January 1992, which regulated the following quality characteristics of the apatite concentrate:

P_2O_5 content not less than 39,0%;
Residue on sieve + 0.16 mm not more than 13,5%;
Sesquioxides content (Fe_2O_3+Al_2O_3) not more than 3,0%.

[1] *Politique de JSC Apatit en vue d'améliorer les propriétés du concentré d'apatite pour les besoins du consommateur*

The apatite concentrate quality parameters given above were mainly oriented to the demands of domestic processing plants and neighbouring countries plants having similar technologies and equipment. The chemical, mineralogical and granulometric compositions of the concentrate produced as a brand “Standard” are demonstrated in Table 1.

Table 1 - Specification of Kola Apatite Concentrate "Standard"

Name	Chemical formula	Content, %
Chemical Characteristics		
Phosphoric pentoxide	P_2O_5	39.00
Ferric oxide	FeO	0.04 - 0.14
Ferric trioxide	Fe_2O_3	0.33 - 0.66
Alumina	Al_2O_3	0.53 - 0.96
Water	H_2O	0.50 - 1.50
Silicon dioxide	SiO_2	1.99 - 2.65
Titanium dioxide	TiO_2	0.24 - 0.61
Calcium oxide	CaO	50.07 - 51.05
Strontium oxide	SrO	2.61 - 3.63
Rare earth iron trioxide	TR_2O_3	0.78 - 0.97
Manganese oxide	MnO	0.02 - 0.05
Magnesium oxide	MgO	0.08 - 0.16
Sodium oxide	Na_2O	0.16 - 0.62
Potassium oxide	K_2O	0.11 - 0.36
Fluorine	F_2	2.65 - 3.19
Mineralogical Characteristics		
Apatite	$Ca_{10}(PO_4)_6(F,OH)_2$	95.00 - 97.20
Nepheline	$KNa_3[AlSiO_4]_4$	0.70 - 3.00
Aegirine	$NaFe[Si_2O_6]$	0.20 - 0.90
Titanite	$CaTiSiO_4(O,OH,F)$	0.10 - 0.50
Titanomagnetite	$(FeFe_2O_4xFe_2TiO_4)$ + $(FeFe_2O_4xFeTiO_3)$	Traces - 0.17
Microline	$K[AlSi_3O_8]$	Traces - 0.20
Libenerite	$KAl_2[AlSi_3O_{10}](OH)_2xnH_2O$	Traces - 0.10
Granulometric Characteristics		
Class + 0.20		1.00 - 5.70
Class - 0.20 + 0.16		7.00 - 12.00
Class - 0.16 + 0.10		19.00 - 24.00
Class - 0.10 + 0.071		6.00 - 15.00
Class - 0.071		47.00 - 58.00

As follows from these data the “Standard” apatite concentrate differs from other phosphate rock types used world-wide by a higher P_2O_5 content being no less than 39,0%, by the sesquioxides content (Fe_2O_3+Al_2O_3) up to 1,0-1,5% which is optimal for sulphuric acid treatment, and lower content of impurities present which when in higher quantities make the acid treatment more complicated, in particular not more than 0,09 % of organic substances and not more than 0,04% of chlorine. This concentrate contains practically no heavy metal ions, such as cadmium, arsenic, mercury, radionuclides and is the ecologically purest raw material in comparison with other types of phosphate rock This fact have been confirmed by “Environment Certificate” given for our production apatite concentrate by wide-known company “TUV” in 1998. The apatite concentrate contains also about 1% of rare earth oxides, 2,6-3,6% of strontium oxides, 2,7-3,2% of fluorine which are extracted at many plants as separate products during acid processing.

Table 2 - Characteristics of main type of raw materials

Source of raw material	Content of P_2O_5, %	Content of detrimental impurities		
		Cd, ppm	F, %	U_3O_2, ppm
Kola Apatite Concentrate	37,2 - 40,0	0,4 - 0,1	2,9 - 3,0	less than 5
Florida, USA	31,1 - 34,3	5 - 15	3,7 - 3,8	78 - 185
Morocco	30,5 - 36,1	10 - 75	3,7 - 4,1	71 - 138
Israel	32,3 - 34,2	15 - 115	3,4 - 3,7	no data
Tunisia	28,8	25 - 35	3,6	no data
Togo	33,8 - 36,7	42 - 80	3,8	no data
Senegal	36,7	66 - 90	3,7	no data
Jordan	30,8 - 34,3	4 - 10	3,8	97 - 152

Source: "World of Sulphur, N, P and K" N° 1, 1997

Moving towards a market economy and maintaining a closer contact with the consumers of the apatite concentrate we found out that the indicated features are not always relevant to each consumer either in terms of main component P_2O_5 and impurities including TiO_2, SiO_2, Fe_2O_3+Al_2O_3 or in terms of flowability and dustiness while handling in ports.

Last years, fulfilling wishes of the customers JSC Apatit established and introduced additionally new apatite concentrate brands “Higher Grade Mix” and “Super” into production. The difference between the above-mentioned brands and “Standard” apatite concentrate is P_2O_5 content (“Higher Grade Mix” - 37,2% P_2O_5 or 81 % BPL and “Super” - 40% P_2O_5 or 87% BPL), TiO_2 being as low as 0,2% and SiO_2 not more than 2% as well as a considerable reduction of fine particles fraction - 0,071 mm not more than 20% that ensures a significant reduction in the dustiness during loading to and discharging from vessels. It should be noted that the concentrates of “Super” and “Higher Grade Mix” brands have the same base - “Super” concentrate. Current the output of the “Super” concentrate amounts to over 900 thousand t per year.

Table 3 - Specification of Kola Apatite Concentrate "Standard", "Super", "Higher Grade Mix"

Name	Chemical formula	Content, %		
		Standard	**Super**	**Higher Grade Mix**
Chemical Characteristics				
Phosphoric pentoxide	P_2O_5	39.00	40.00	37.80
Ferric oxide	FeO	0.04 - 0.14	0.01 - 0.03	0.01 - 0.02
Ferric trioxide	Fe_2O_3	0.33 - 0.66	0.40 - 0.50	0.44 - 0.48
Alumina	Al_2O_3	0.53 - 0.96	0.35 - 0.60	1.38 - 1.78
Water	H_2O	0.50 - 1.50	0.50 - 1.50	0.50 - 1.50
Silicon dioxide	SiO_2	1.99 - 2.65	1.90 - 2.10	3.40 - 3.90
Titanium dioxide	TiO_2	0.24 - 0.61	0.15 - 0.25	0.14 - 0.24
Calcium oxide	CaO	50.07 - 51.05	50.80 - 51.30	48.30 - 49.30
Strontium oxide	SrO	2.61 - 3.63	2.70 - 2.90	2.50 - 2.90
Rare-earth iron trioxide	TR_2O_3	0.78 - 0.97	0.85 - 0.95	0.83 - 0.93
Magnese oxide	MgO	0.08 - 0.16	0.05 - 0.10	0.06 - 0.11
Sodium oxide	Na_2O	0.16 - 0.62	0.35 - 0.45	0.90 - 1.05
Potassium oxide	K_2O	0.11 - 0.36	0.10 - 0.20	0.28 - 0.40
Fluorine	F_2	2.65 - 3.19	3.30 - 3.40	2.90 - 3.00
Mineralogic Characteristics				
Apatite	$Ca_{10}(PO_4)_6(F_2OH)_2$	80.00 - 83.00	97.20 - 98.00	80.75 - 82.19
Nepheline	$KNa_3[AlSiO_4]_4$	8.00 - 11.00	0.80 - 1.40	13.20 - 14.48
Aegirine	$NaFe[Si_2O_6]$	4.00 - 4.70	0.80 - 0.40	13.20 - 14.48
Titanite	$CaTiSiO_4(O, OH, F)$	0.10 - 0.50	Traces - 0.15	Traces - 0.20
Titanomagnetite	$(FeFe_2O_4*Fe_2TiO_4)+(FeFe_2O_4*FeTiO_3)$	Traces - 0.17	Traces	Traces
Lamprohyllite	$Sr\{Na_3Ti[Ti_2*(Si_2O_3)_2]O_2F$	Traces	Traces - 0.15	Traces 0.15
Ilmenite	$FeTiO_3$	Traces	Traces	Traces
Microline	$K[AlSi_3O_3]$	Traces - 0.20	Traces - 0.15	Traces - 0.15
Libenerite	$KaI_2[AlSi_3O_{10}](OH)*nH_2O$	Traces - 0.10	Traces	Traces
Granulometric Characteristics				
+ 0.32		-	1.30 - 2.00	1.30 - 1.90
- 0.32 + 0.20		1.00 - 5.70	15.00 - 17.00	16.00 - 18.00
- 0.20 + 0.16		7.00 - 12.00	21.50 - 23.50	20.90 - 21.90
- 0.16 + 0.10		19.00 - 24.00	30.50 - 32.50	31.70 - 33.70
- 0.10 + 0.071		6.00 - 15.00	7.00 - 8.00	7.90 - 9.90
- 0.071		47.00 - 58.00	20.00 - 22.00	16.90 - 18.90

In 1997, after carrying out investigations, new production technologies of “Super” and “Higher Grade Mix” were developed and tested which allow to reach an annual output of these brands up to 1,1-1,2 million t by the end of 1998. It is planned to increase “Super” and “Higher Grade Mix” brands output up to 2,0 – 2,3 million t per year by 2003-2005 in the course of realization of JSC Apatit’s optimal development program.

Table 4 - The potential volumes of apatite concentrate export 1998-2005

N°	Apatite Concentrate Grade	Expected delivery volume ('000 tonnes)																	
		1998		1999		2000		2001		2002		2003		2004		2005		On average	
		Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
1	Mixed	295	355	295	355	295	355	295	355	295	355	295	355	295	355	295	355	295	355
2	Super	270	390	270	390	270	390	270	390	270	390	270	390	270	390	270	390	270	390
3	Super	150	200	150	200	150	200	150	200	150	200	150	200	150	200	150	200	150	200
4	Super	40	50	40	50	40	50	40	50	40	50	40	50	40	50	40	50	40	50
5	Super	50	100	150	350	300	450	300	450	300	350	300	350	300	350	300	350	250	343.75
6	Super	40	80	80	150	200	400	300	500	450	650	450	650	450	650	450	650	302.5	466.25
	Total	**845**	**1175**	**985**	**1495**	**1255**	**1845**	**1355**	**1945**	**1505**	**1995**	**1505**	**1995**	**1505**	**1995**	**1505**	**1995**	**1307.5**	**1805**

Production possibilities of JSC Apatit allow to broaden the range of apatite concentrate with different P_2O_5 contents, for instance, “Apatite Concentrate of Main Flotation ” and “Mix N° 1".

Table 5 - Specification of Kola Apatit Concentrate "Main Flotation" and "Mix N°1"

Name	Chemical formula	Content, %	
		Main Flotation	Mix N° 1
Chemical Characteristics			
Phosphoric pentoxide	P_2O_5	32.00 - 34.00	33.18 - 33.52
Ferric oxide	FeO	0.40 - 0.70	0.16 - 0.20
Ferric trioxide	Fe_2O_3	1.70 - 2.20	0.60 - 0.86
Alumina	Al_2O_3	3.00 - 4.00	4.74 - 5.08
Water	H_2O	0.50 - 1.50	0.50 - 1.50
Silicon dioxide	SiO_2	7.80 - 9.20	8.45 - 8.88
Titanium dioxide	TiO_2	0.80 - 1.20	0.33 - 0.50
Calcium oxide	CaO	43.00 - 44.50	42.73 - 43.58
Strontium oxide	SrO	2.00 - 2.40	2.21 - 3.00
Rare-earth iron trioxide	TR_2O_3	0.55 - 0.66	0.72 - 0.81
Manganese oxide	MnO	0.05 - 0.10	0.05 - 0.06
Magnesium oxide	MgO	0.35 - 0.55	0.16 - 0.42
Sodium oxide	Na_2O	1.60 - 2.20	1.93 - 2.27
Potassium oxide	K_2O	0.70 - 0.90	1.18 - 1.43
Fluorine	F_2	2.30 - 2.70	2.56 - 2.73
Mineralogic Characteristics			
Apatite	$Ca_{10}(PO_4)_6(F_2OH)_2$	80.00 - 83.00	80.75 - 82.19
Nepheline	$KNa_3[AlSiO_4]_4$	8.00 - 11.00	13.20 - 14.48
Aegirine	$NaFe[Si_2O_6]$	4.00 - 4.70	1.09 - 1.51
Titanite	$CaTiSiO_4(O, OH, F)$	0.90 - 1.50	0.32 - 0.58
Microcline	$K[AlSi_3O_8]$	1.00 - 2.10	1.89 - 2.06
Lepidomelane	$KFe[(Al_2Fe)Si_3O_{10}](OH)_2$	Traces - 0.15	Traces
Titanomagnetite	$(FeFe_2O_4*Fe2TiO_4)+(FeFe_2O_4*FeTiO_3)$	Traces - 0.20	Traces
Lamprofphyllite	$Sr\{Na_3Ti[Ti_2*(Si_2O_7)_2]O_2F\}$	Traces - 0.40	Traces
Ilmenite	$FeTiO_3$	Traces	Traces
Libenerite	$KAl_2[AlSiO_3O_{10}](OH)_2*nH_2O$	Traces - 0.20	0.15 - 0.38
Granulometric Characteristics			
+ 0.32		0.50 - 2.00	-
- 0.32 + 0.20		4.50 - 7.00	-
- 0.20 + 0.16		8.00 - 12.00	15.90 - 18.20
- 0.16 + 0.10		17.00 - 19.50	43.10 - 52.50
- 0.10 + 0.071		5.00 - 8.00	-
- 0.071		52.00 - 59.00	-

Dustiness of the apatite concentrate particularly of “Standard” brand causes certain difficulties during handling and is connected with the moisture and fine particles less than 20 microns contents. Investigations have revealed that when the moisture content is 1,5% and higher relative dustiness reduces by several times in comparison with the lowest permissible moisture limit - 0,5%.

In 1996-1997, the practice of loading and discharging operations in the commercial sea port of Murmansk and ports of Europe and Asia was generalized and it was analyzed how moisture content changes during transportation in railcars and vessels.

The results obtained have demonstrated that the existing requirements of GOST on moisture 1,0 ± 0,5% in winter and 1,5 ± 0,5% in summer period ensure a satisfactory handling at a moderate dustiness but not within the whole moisture content range. The apatite concentrate having moisture of 1,5% and more which provides low dustiness is characterized by insufficient flowability and makes the discharging from railcars at Murmansk

port difficult and reduces the efficiency when unloaded from vessels in particular when screw unloading is

applied and during transshipments from hoppers at consumers' sites. Furthermore it was found out that the apatite concentrate containing over 1,5% moisture is inclined to freezing together and freezing to metallic walls of railcars and transfer hoppers. Laboratory investigations on estimation of apatite concentrate flowability carried out by Karra's method have demonstrated that permissible or satisfactory flowability can be obtained when the moisture is not higher than 1,0-0,8%.

To solve the question how to optimize the dustiness and flowability a program on improving the quality and consumers' properties of the apatite concentrate has been developed in 1998, which pays much attention to stabilization of drying process of the apatite concentrate and lowering of permissible variations in moisture content down to $\pm$ 0,2 of nominal ones what in our opinion will allow to improve essentially its physical properties in terms of flowability and dustiness and to meet requirements of various consumers.

A number of actions have been planned by JSC Apatit to update the production technology. They are targeted at lowering fine particle content in the course of the apatite concentrate production. The basic actions are:

- reducing of particle size of the ore crushed from 25 mm down to 18 mm;
- strengthening of classification efficiency in grinding process from 65% to 80-90%;
- increasing of practical size of crushing to 25-26% in class with obtaining of the concentrate of practical size 13,5-16,5%.

These actions are to ensure a reduction of fine classes content generating dust (-20 microns) in the merchant apatite concentrate by 20-30 of relative percent.

Besides that we conducted investigations using different types of binders with lump-formation of the apatite concentrate. Realization of this trend leads to a reduction in dustiness of 4-5 times comparing to the present situation.

Apatit's technologists have solved this problem for production process and have prepared all the documents and methodical materials to commence operation in 1999. However, before the consumers' approval on acceptance of a coarse product with addition of binders is obtained these operations have been suspended. Thus, proceeding from the stated above JSC Apatit gives the most serious attention to improving of controlling methods of P_2O_5 content, moisture content and granulometry. Controlling methods applied at present provide guarantee and acceptance of other customers. So, for example, during 1995-1997 rather high acceptance was observed with BASF, Rhone Poulenc (Rhodia), Prayon and Norsk Hydro data on the above-mentioned elements.

Practice of constant exchange of information on quality and moisture analyses allowed to exclude almost all claims from the consumers' side. For instance, the JSC Apatit results and Norsk Hydro's results compared over more than 300 000 t of apatite concentrate deliveries in 1997 differed in terms of P_2O_5 by $\pm$ 0,02%, in terms of H_2O by $\pm$ 0,08% when the maximum differences in individual shipments in terms of P_2O_5 and H_2O were 0,2% and 0,3% respectively.

The good routine analysis of practically every component have been made in two trial lots of the apatite concentrate to India in 1998.

JSC Apatit has always been working and will continue working on improving the apatite concentrate specifications with the view of satisfying our clients' requirements.

Figure 1 - The Kola Peninsula's Map

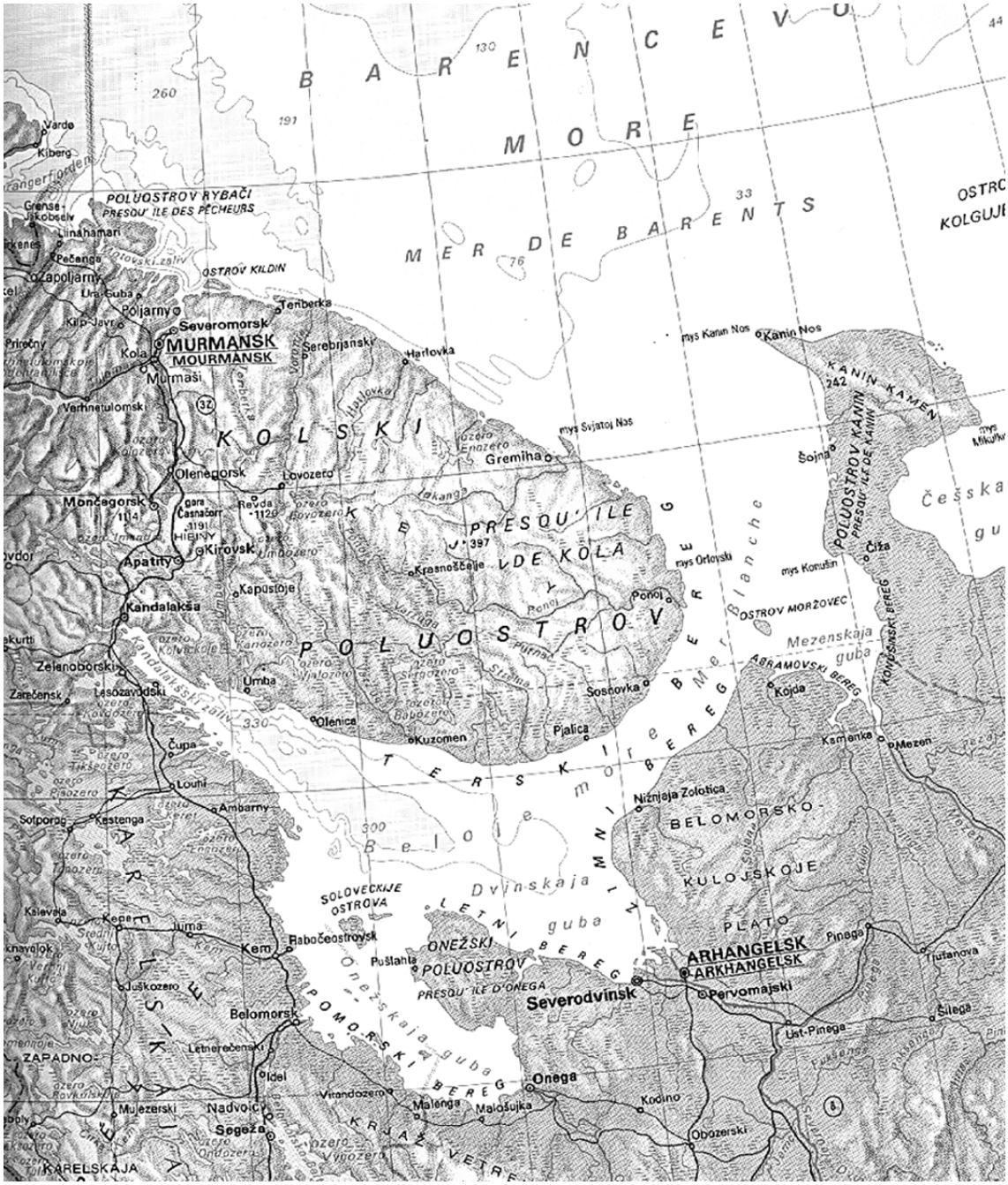

Figure 2 – Basic diagram of apatite-nepheline ore processing