Kola Science Centre of the Russian Academy of Sciences
Institute of North Industrial Ecology Problems

Industrial Ecology Laboratory

Decrease the environmental hazard of mining waste and developing ecofriendly processes

Dmitriy Makarov

Main tailings ponds in Murmansk Region*

No	Facility	Operating period	Total area, ha	Reserves, Mt	Valuable components
1	Tailings pond, Pechenganickel Plant 1, JSC Kola MMC	1965 - present time	1033	~280	Ni, Cu, Co
2	Tailings pond, Pechenganickel Plant 2, JSC Kola MMC	1945 - 1994		22.4	Ni, Cu, Co
3	Tailings pond, Apatite-Nepheline Plant 1 (ANOF 1), JSC Apatit	1957 - 1962	120	24.4	P_2O_5, Al_2O_3, TiO_2
4	Tailings pond, Apatite-Nepheline Plant 2 (ANOF 2), JSC Apatit	1968 - present time	1652	~550	P_2O_5, Al_2O_3, TiO_2
5	Tailings pond, Apatite-Nepheline Plant 3 (ANOF 3), JSC Apatit	1963 - present time	1158	~250	P_2O_5, Al_2O_3, TiO_2
6	Tailings pond, JSC Kovdorsky GOK, (Site 1)	1962 -1980	330	53.8	P_2O_5, ZrO_2
7	Tailings pond, JSC Kovdorsky GOK, (Site 2)	1988 - present time	900	80	P_2O_5, ZrO_2

*M.A. Nevskaya, S.G. Seleznev, V.A. Masloboev, E.M. Klyuchnikova, D.V. Makarov, Environmental and business challenges presented by mining and mineral processing waste in the Russian Federation. Minerals. 9 (2019) 445; doi:10.3390/min9070445

Water Consumption by Mining Enterprises

No	Mining Enterprise	Major Production	The yearly mine water flow, mln m^3
1	JSC Apatit	Phosphate ore	**~170**
2	JSC Kovdorsky GOK	Phosphate ore, zirconium, iron ore	**~ 40**
3	JSC Olkon	Iron ore	**~ 2**
4	JSC Kola MMC	Nickel, copper, cobalt, PGM	**~10**
5	Lovozersky GOK LTD	Rare earth metals, tantalum, niobium, titanium	**~10**

The Laboratory is focusing on finding solutions

to the following problems:

- development of land reclamation methods for mining waste dumps;
- development of industrial processes for further recovery of valuable components from waste, including parallel production of building materials;
- development of methods for protecting natural water bodies and treating wastewater to remove heavy metals, sulfates, fluorine, petroleum products, and suspended solids.

Development of Conservation and Reclamation Methods for Mining Waste Dumps

ISSN 1062-7391, Journal of Mining Science, 2018, Vol. 54, No. 2, pp. 329–338. © Pleiades Publishing, Ltd., 2018.
Original Russian Text © V.A. Masloboev, A.V. Svetlov, O.T. Konina, G.V. Mitrofanova, A.V. Turtanov, D.V. Makarov, 2018, published in Fiziko-Tekhnicheskie Problemy Razrabotki Poleznykh Iskopaemykh, 2018, No. 2, pp. 161–171.

MINING ECOLOGY AND EXPLOITATION OF THE EARTH'S BOWELS

Selection of Binding Agents for Dust Prevention at Tailings Ponds at Apatite–Nepheline Ore Processing Plants

V. A. Masloboev[a]*, A. V. Svetlov[b], O. T. Konina[c], G. V. Mitrofanova[d], A. V. Turtanov[e], and D. V. Makarov[b]

DOI 10.1007/s10749-019-01033-9
Power Technology and Engineering *Vol. 53, No. 1, May, 2019*

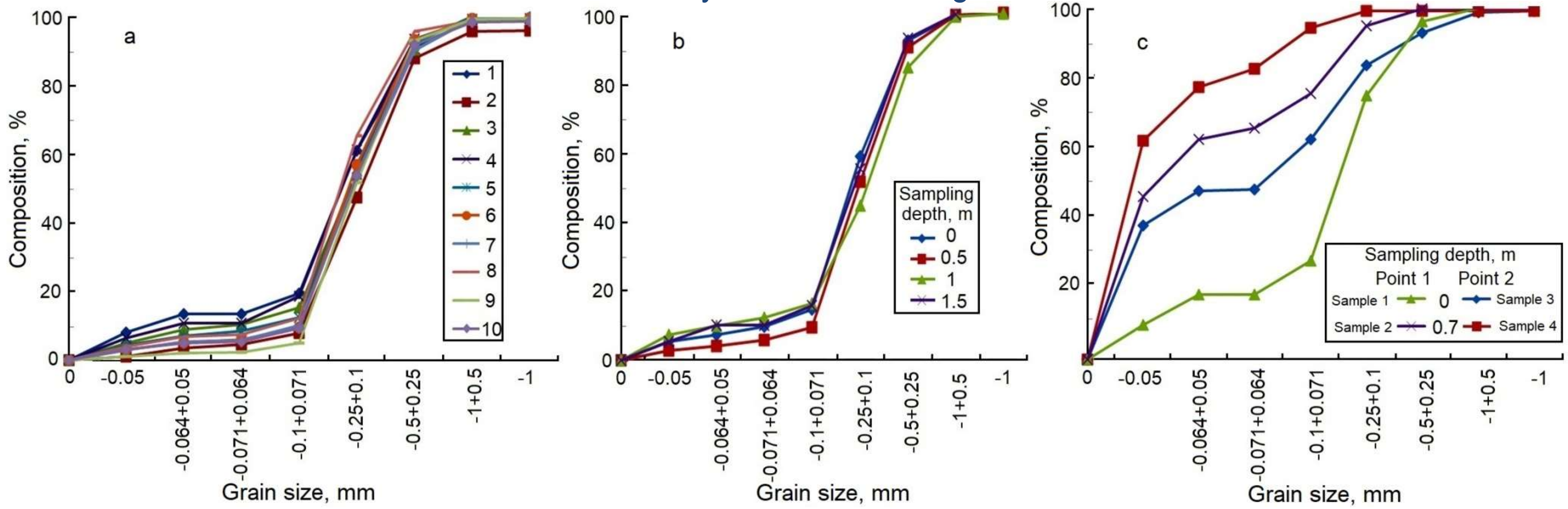
SOME ASPECTS OF PHYSICOCHEMICAL AND BIOLOGICAL METHODS FOR THE CONSERVATION OF APATITE-NEPHELINE TAILINGS IN THE FAR NORTH

L. A. Ivanova,[1] T. T. Gorbacheva,[2] D. V. Makarov,[2] and A. V. Rumyantseva[3]

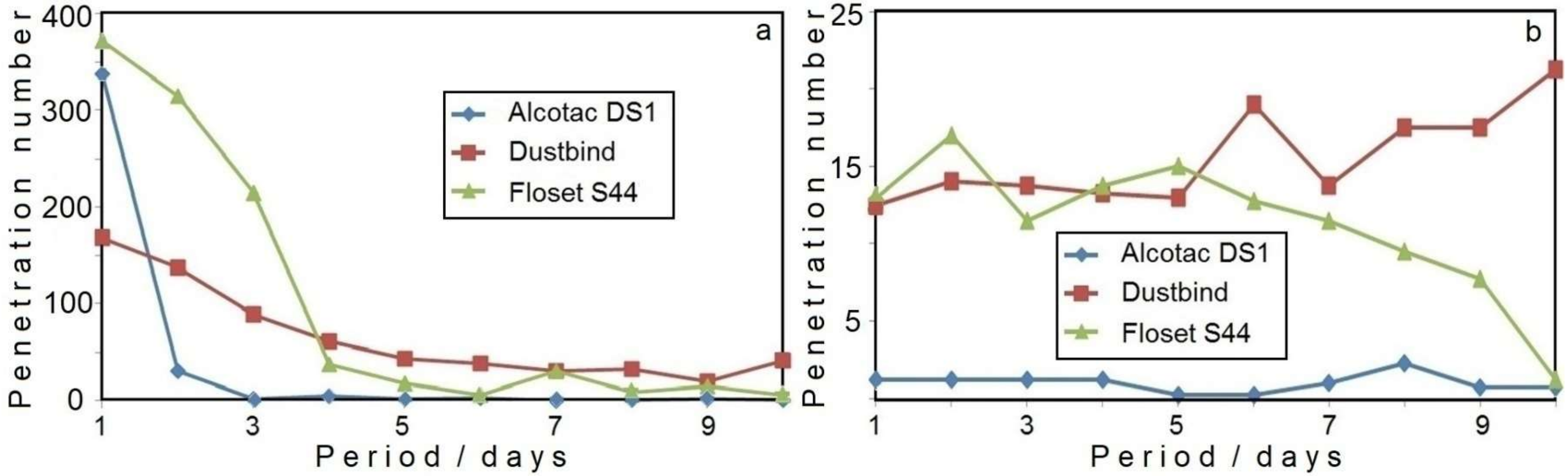
Comparison of binding agents for fixation of dusting surfaces of tailing ponds of apatite-nepheline processing plant No. 2, JSC Apatit

Study area layout

Cumulative curves of flotation tailings grain size composition in the site with expected appliance of binding agents: (a) samples of the surface layer; (b) pit-hole samples; (c) grain size composition of recently alluviated tailings

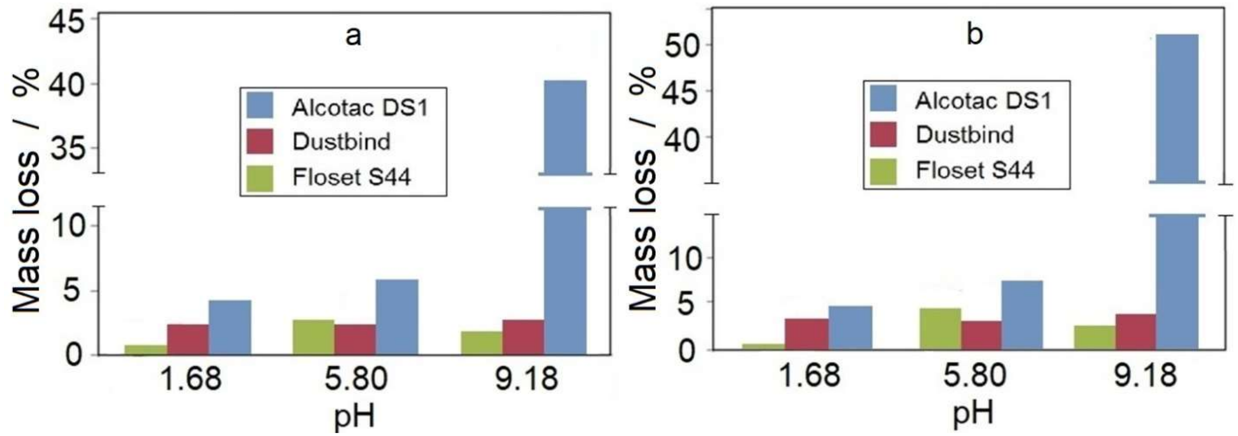


Change of the coating strength conditions during 10 days from the moment of applying the solution of an agent (a) and within 10 days (cycles) of “freezing–thawing” (b)



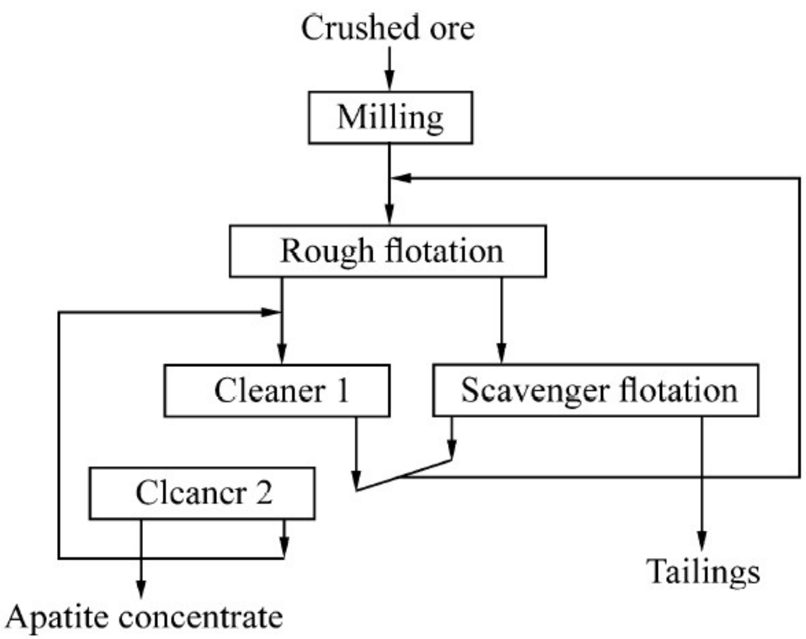
Testing site (1) and dusting of untreated tailings (2) near it

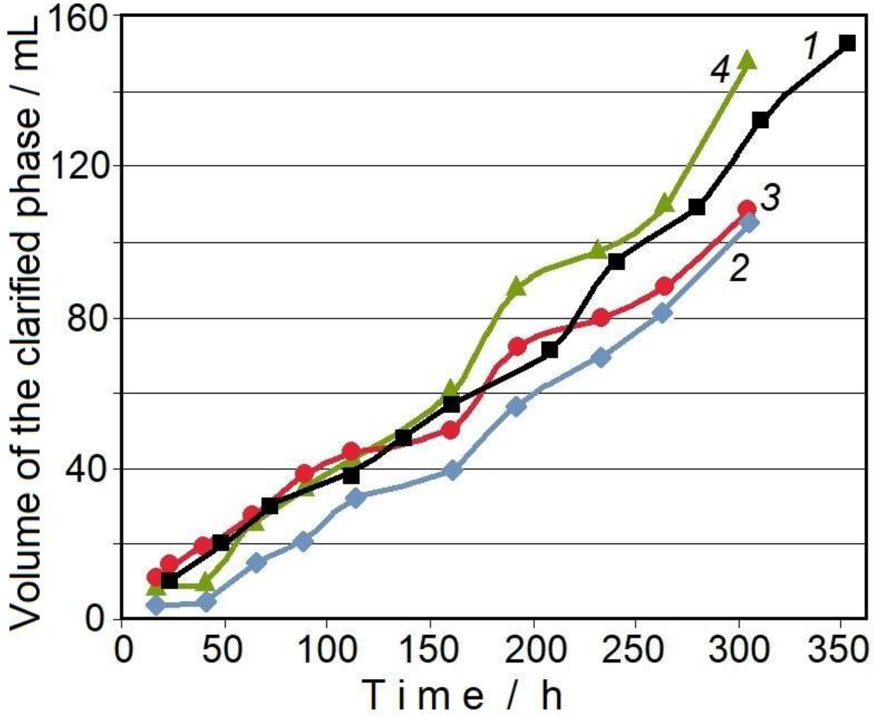
Dependence of the mass loss of the agents coatings after leaching for 4 days (a) and 7 days (b)



Kinetics of the clarified circulating water (1) and the circulating water at the agent concentration, mgL: 8.6—Alcotac DS1 (2), 8.5—Dustbind (3), 7.2—Floset S44 (4)

Schema flotation in a closed circuit





Reagent introduction by cross-country vehicle

Before

Now

Development of Industrial Processes for Recovery of Valuable Components from Mining Waste

Perspectives for Heap Leaching of Non-Ferrous Metals (Murmansk Region, Russia)

Anton SVETLOV[1)], Elena KRAVCHENKO[1),2)], Ekaterina SELIVANOVA[3)], Sergey SELEZNEV[4)], Dmitry NESTEROV[5)], Dmitry MAKAROV[1),2)], Vladimir MASLOBOEV[1),2)]

minerals

MDPI

Article

Hydrometallurgical Processing of Low-Grade Sulfide Ore and Mine Waste in the Arctic Regions: Perspectives and Challenges

Vladimir A. Masloboev [1], Sergey G. Seleznev [2], Anton V. Svetlov [1] and Dmitriy V. Makarov [1,*]

minerals

MDPI

Case Report

Environmental and Business Challenges Presented by Mining and Mineral Processing Waste in the Russian Federation

Marina A. Nevskaya [1], Sergey G. Seleznev [2], Vladimir A. Masloboev [3], Elena M. Klyuchnikova [3] and Dmitriy V. Makarov [3,*]

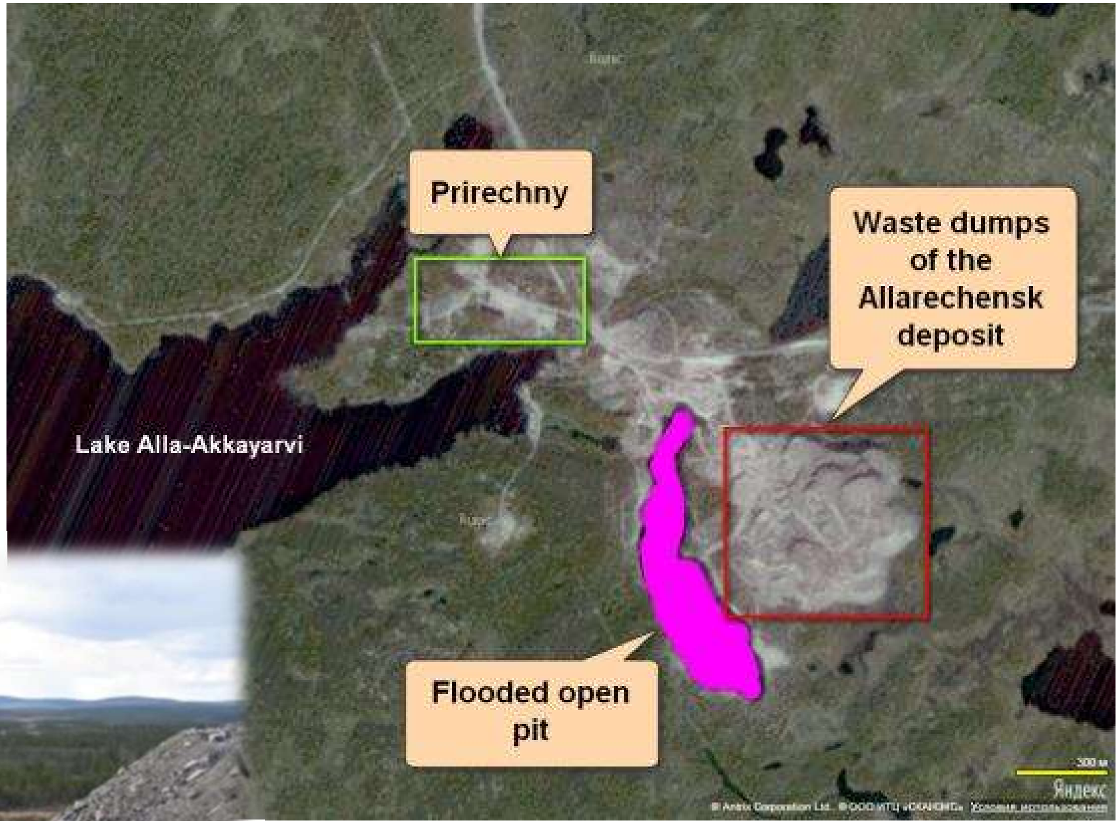
Potential environmental hazard and suitability for bioleaching of low-grade copper-nickel ores and technogenic mineral formation

Site	NAP	Potential environmental hazard	Heap leachability
Low-grade Monchepluton Cu-Ni ores			
Deposit Nyud II (Monchegorsk District)	+81.99	Elevated. AMD*, heavy metal migration	Good
Deposit Nyud Terrace (Monchegorsk District)	+36.51	Average. AMD, heavy metal migration	Satisfactory
Deposit Morozhkovoye Lake (Monchegorsk District)	+63.57	Average. AMD, heavy metal migration	Good
Deposit Nittis-Kumuzja-Travjanaja (Monchegorsk District)	+91.87	Elevated. AMD, heavy metal migration	Good
Technogenic mineral formation			
Allarechensky Deposit dumps (Pechenga District)	+104.37	High. AMD, intensive heavy metal migration	Good
Concentration tailings of Cu-Ni ores (Pechenga District)	+5.35	Moderate. AMD neutralization, heavy metal precipitation by hydrosilicates	Satisfactory. Agglomeration required. Increased sulfuric acid feed rate
Dump slags (Pechenga District)	+4.84	Moderate. Sulfides in the silicate matrix limit AMD	Satisfactory. Grinding and agglomeration required

Notes. NAP – net acid potential, AMD – acid mine drainage

Allarechensky Cu-Ni Ore Deposit Dumps

The deposit represents rock refuses formed during ore extraction in the primary deposit of sulfide copper-nickel ores, where opencast mining was stopped in 1971.

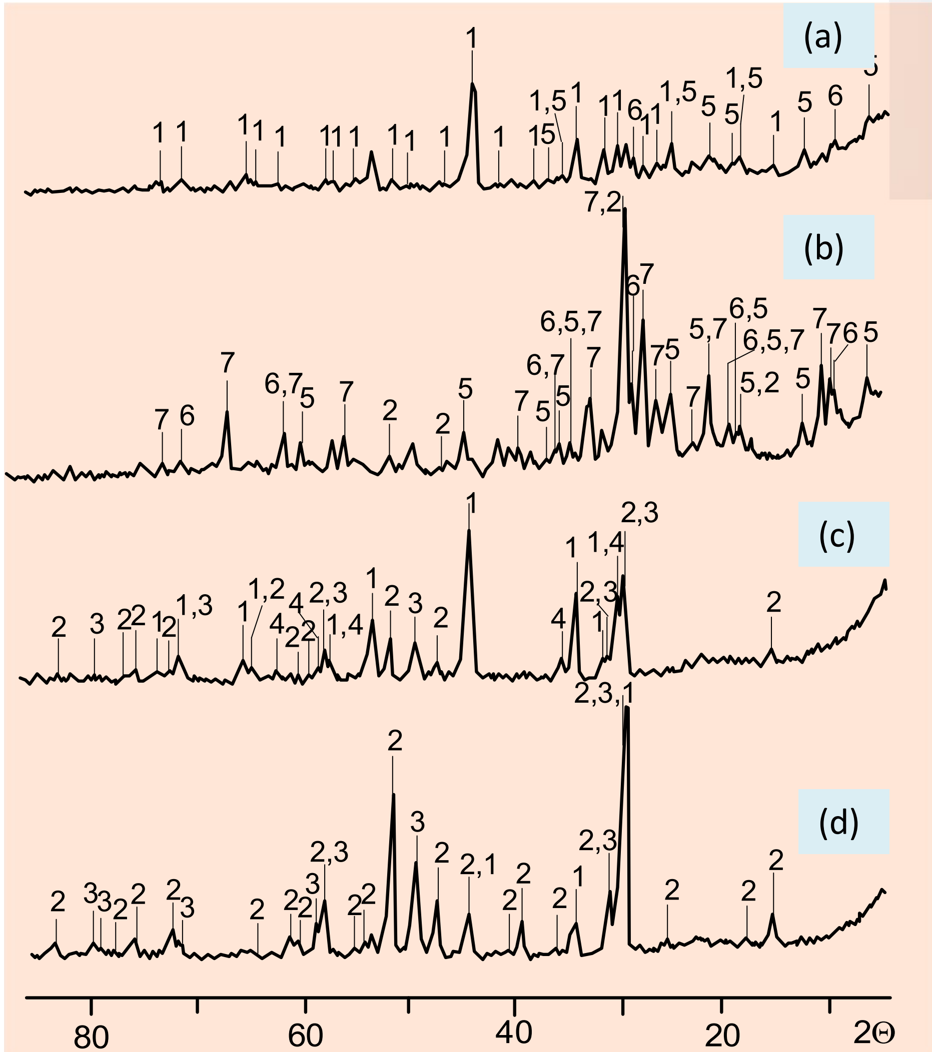


Total surface area of the waste dump is 33 ha, and the rock volume amounts to 6.7 million m^3. The rocks of the dumping site represent overburden chiefly valueless gneisses, granite-gneisses, amphibolites and enclosing rocks mineralized to different extents: peridotites, olivinites, contact amphibolites, etc.

Samples of massive ore

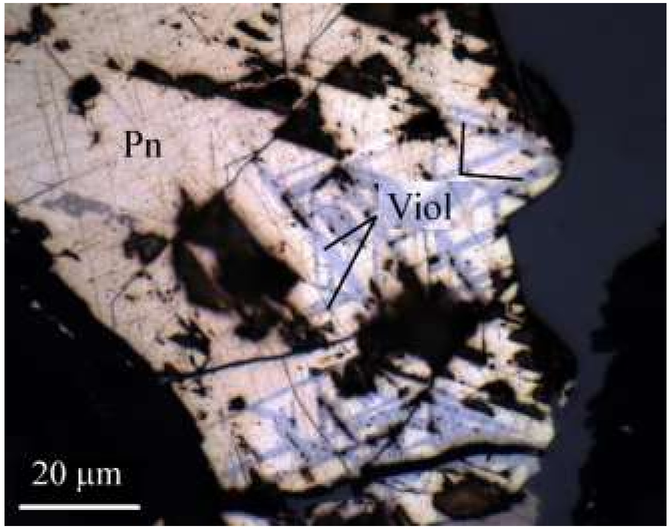
Diffractograms of samples of massive copper-nickel ores

Magnetic (a, c) and nonmagnetic (b, d) fractions



1 - pyrrhotite;
2 - pentlandite;
3 - chalcopyrite;
4 - magnetite;
5 - chlorite;
6 - talc;
7 - amphibole

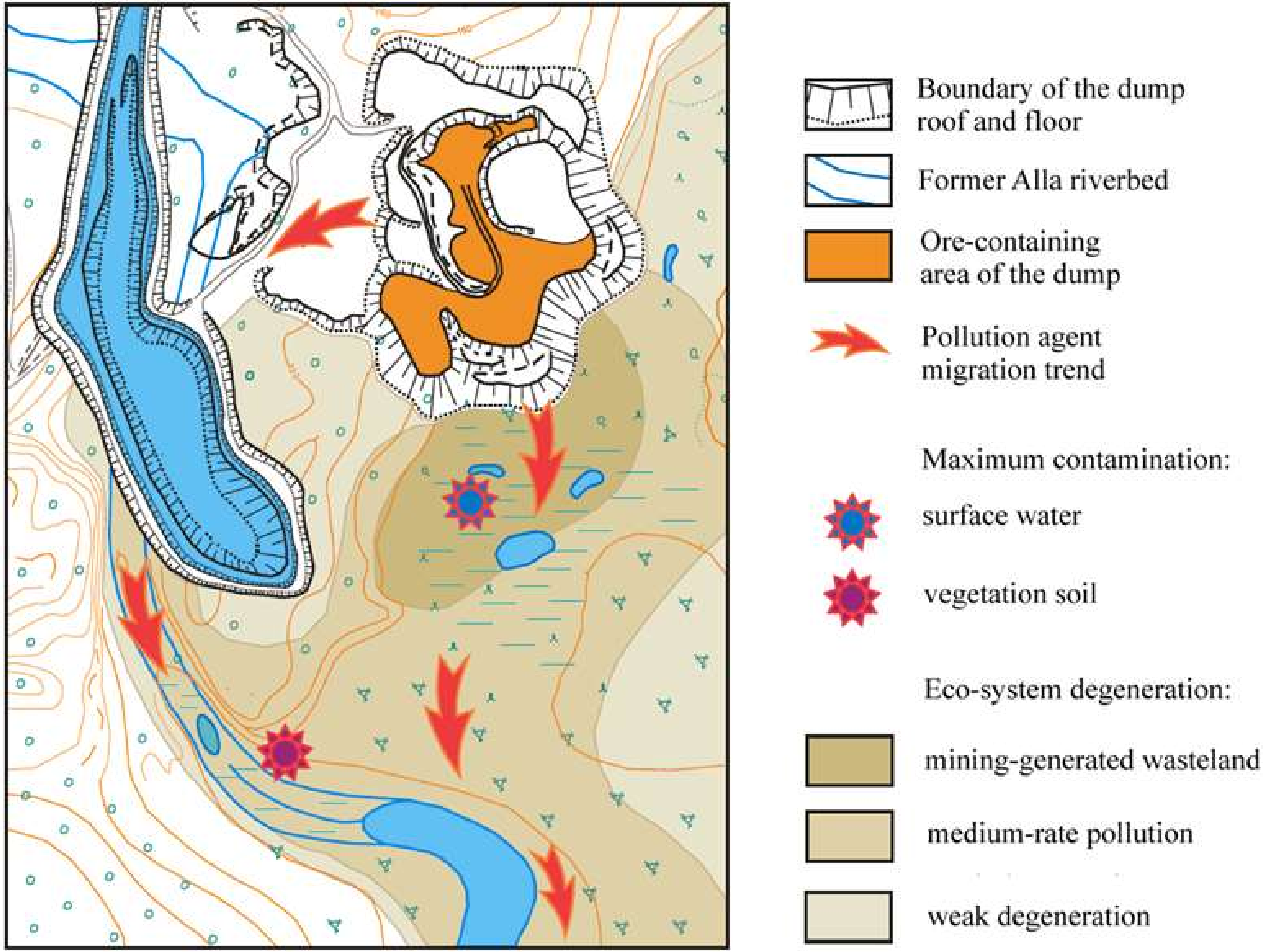
Violarite developed along cleavage of pentlandite



Flooded open pit

Alla river channel

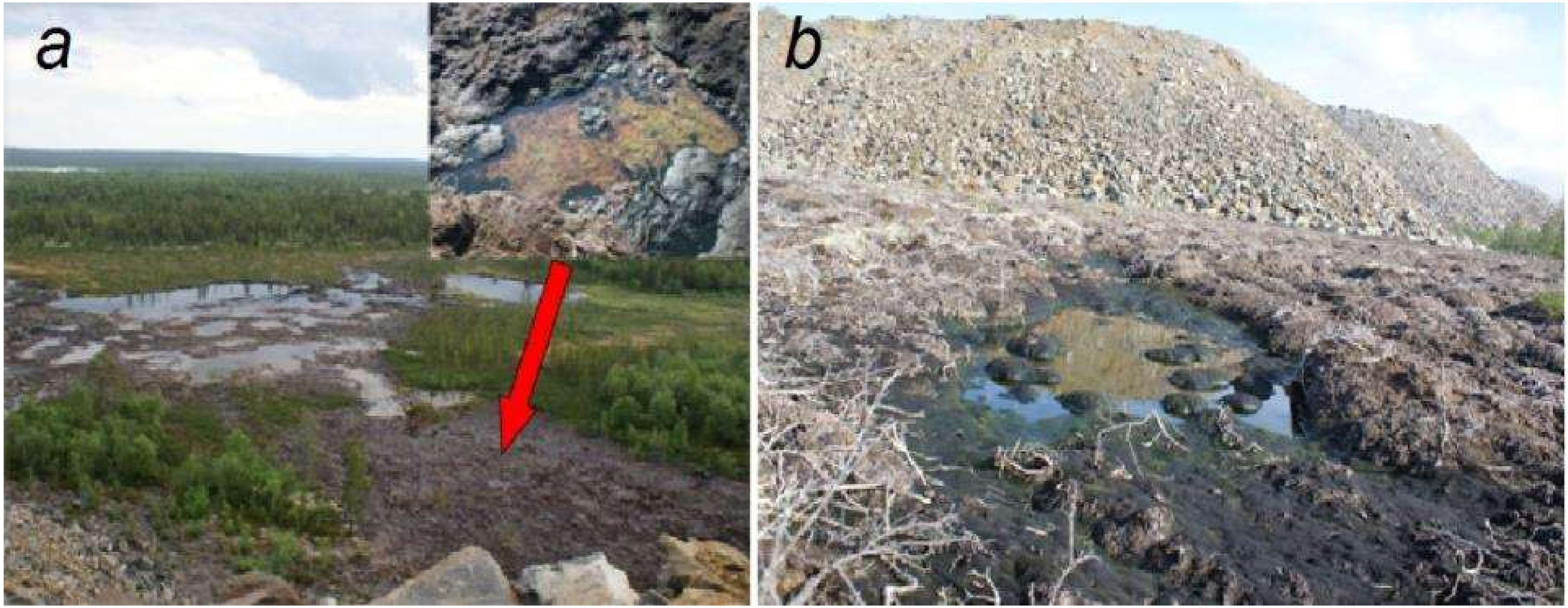
Location plan: Allarechensky Deposit Dumps



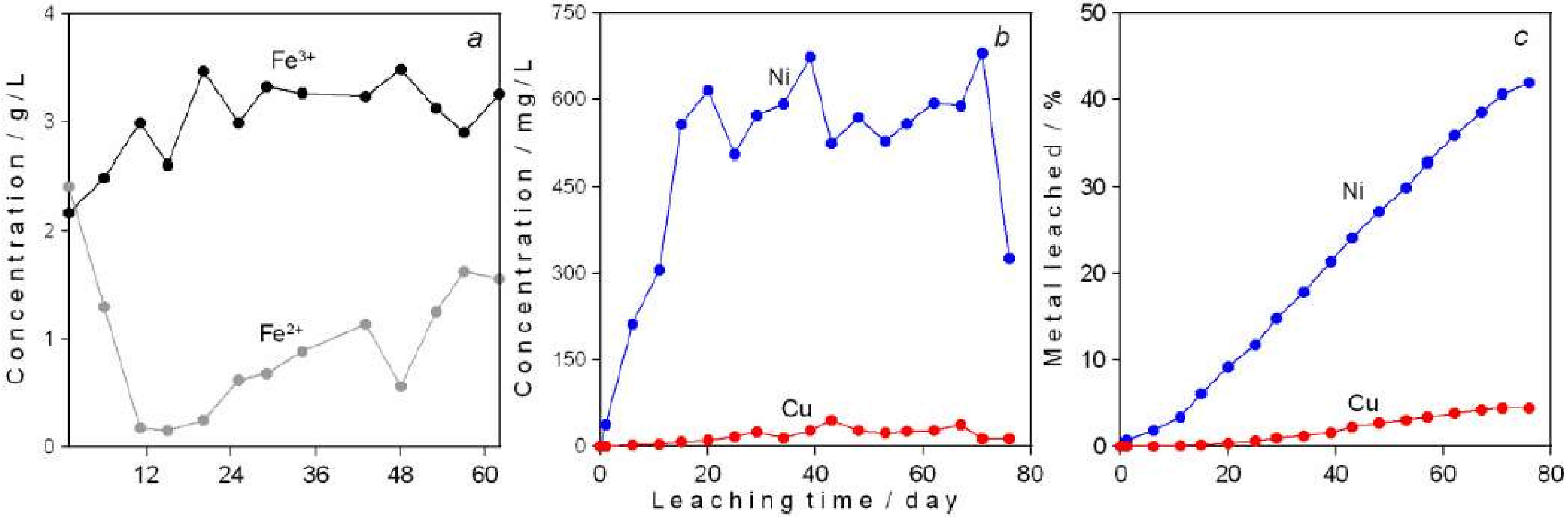
Eco-damage:

(a) southern site of the dump;

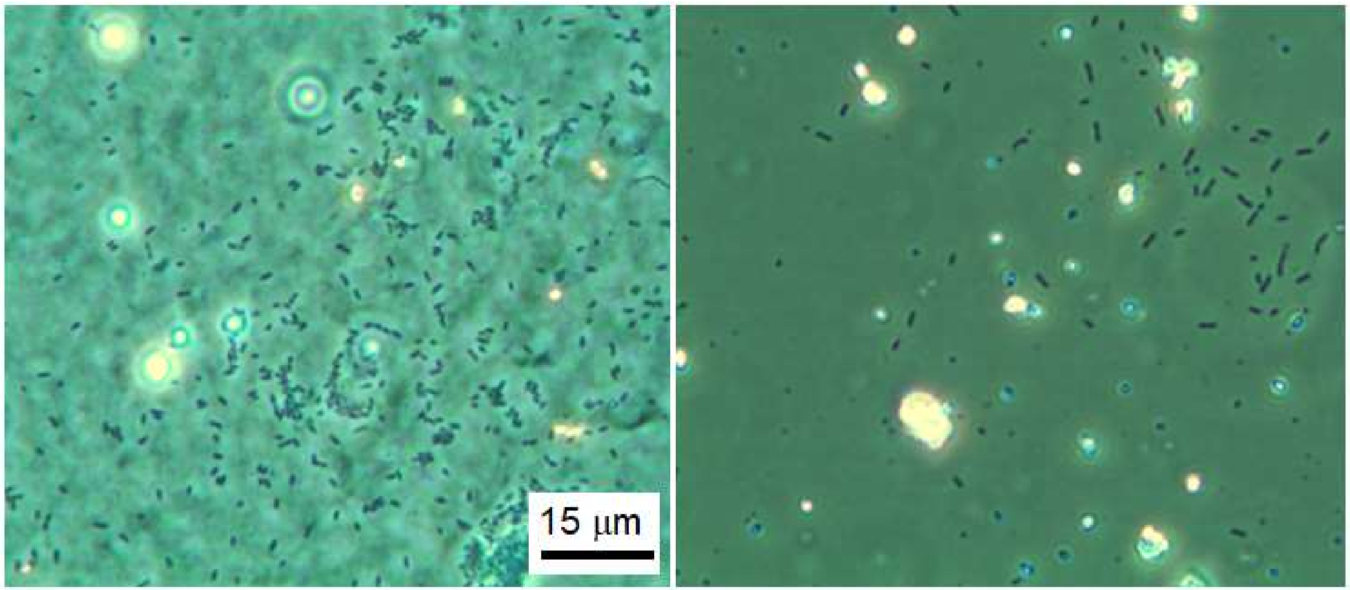
(b) mining-generated wasteland



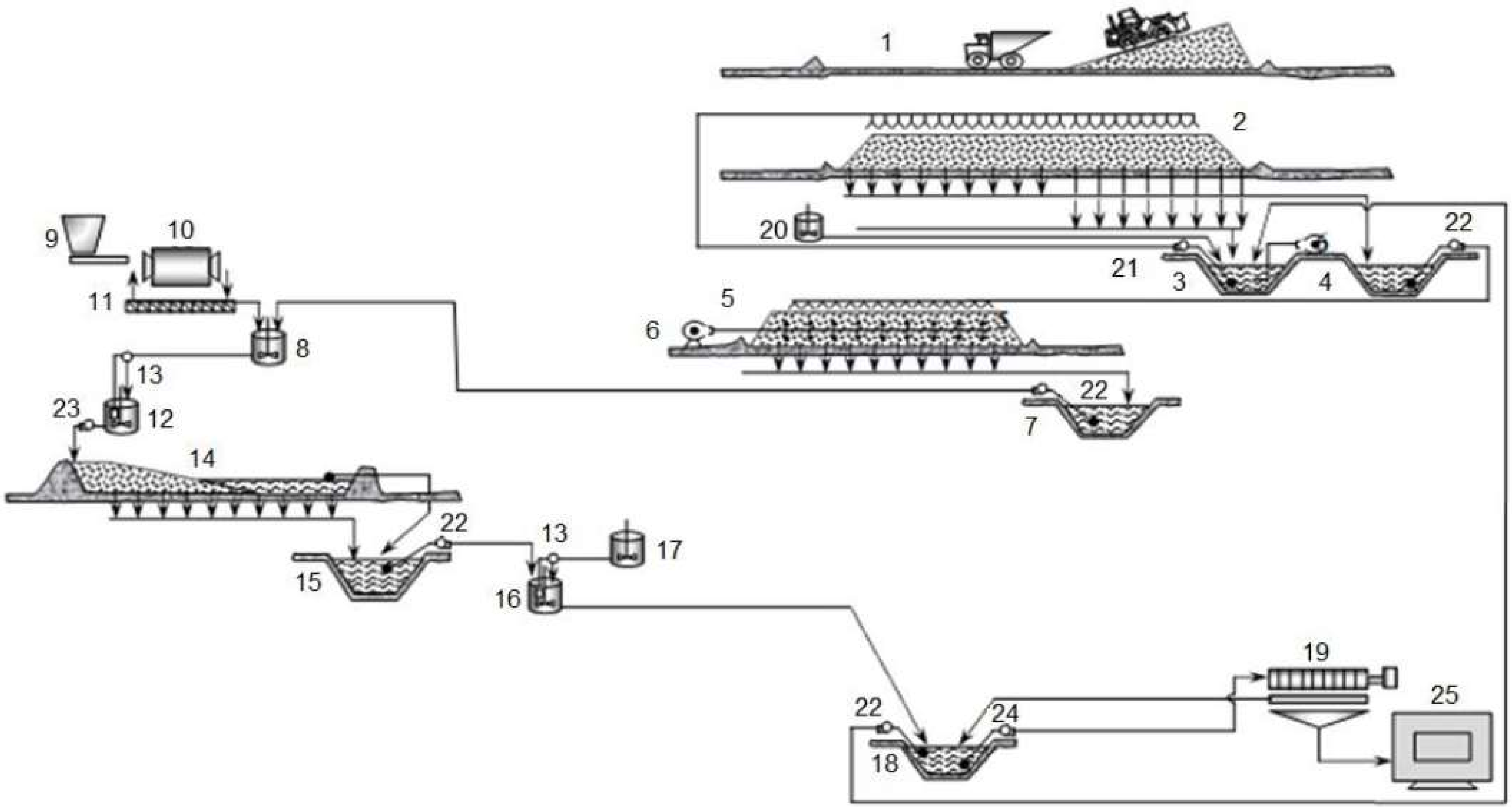
Heap bioleaching of a low-grade copper-nickel ore and minind waste



Ferrous and ferric ion concentrations (a), non-ferrous metal concentrations in the leach solutions (b), and their extraction (c)



Process flow diagram of the ore heap leaching at the Allarechensky Deposit Dumps



1—heap at the forming stage; 2—heap at the irrigation stage; 3—raffinate pond; 4—pregnant leach solution (PLS) pond; 5—heap for iron oxidation; 6—aeration system; 7—oxidized PLS pond; 8—neutralizing tank; 9—crushed lime bunker; 10—ball mill; 11—spiral classifier; 12—setting tank; 13—automatic titration system; 14—sludge storage; 15—storage pond for neutralized PLS; 16—precipitating tank; 17—reagent tank; 18—settling pond; 19—filter-press; 20—bacteria cultivation tank; 21–24 —pumps; 25—furnace

Ceramic Building Materials from Mining and Metallurgical Waste

Applied Clay Science 135 (2017) 199–205

Contents lists available at ScienceDirect

Applied Clay Science

journal homepage: www.elsevier.com/locate/clay

ELSEVIER

Research paper

Electrochemical modification of saponite for manufacture of ceramic building materials

CrossMark

Valentine Chanturiya [a], Vladimir Minenko [a], Olga Suvorova [b], Vera Pletneva [b], Dmitriy Makarov [c,*]

Construction and Building Materials 153 (2017) 783–789

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

ELSEVIER

Construction ceramics from ore dressing waste in Murmansk region, Russia

CrossMark

Olga Suvorova [a], Victoria Kumarova [a], Dmitriy Nekipelov [b], Ekaterina Selivanova [c], Dmitriy Makarov [b,*], Vladimir Masloboev [d]

applied sciences

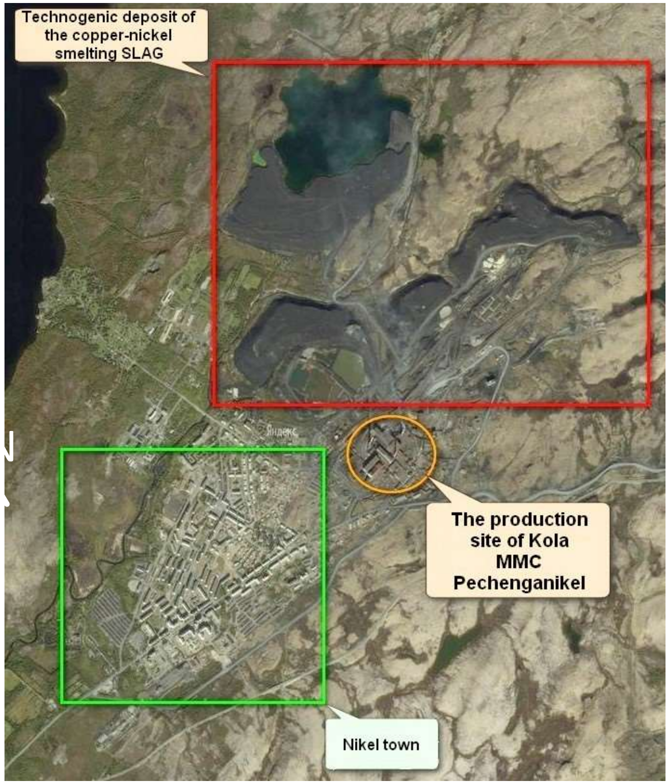
MDPI

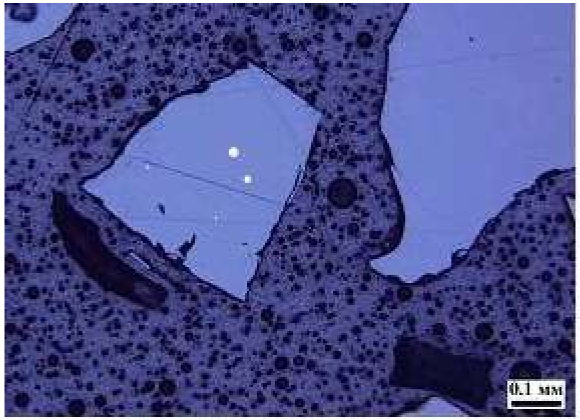
Article

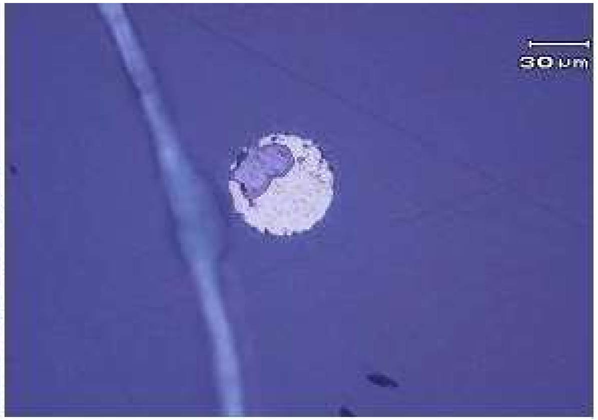
Ceramic Products from Mining and Metallurgical Waste

Olga V. Suvorova [1], Ekaterina A. Selivanova [2], Julia A. Mikhailova [2], Vladimir A. Masloboev [3] and Dmitriy V. Makarov [3,*]

Copper-nickel smelting slag







The optimal ratio of components was, %: slag (CNS) 40, apatite-nepheline ore concentration tailings (ANT) 40, iron ore concentration tailings (FQT) 20.

Chemical composition of the ceramic charge components

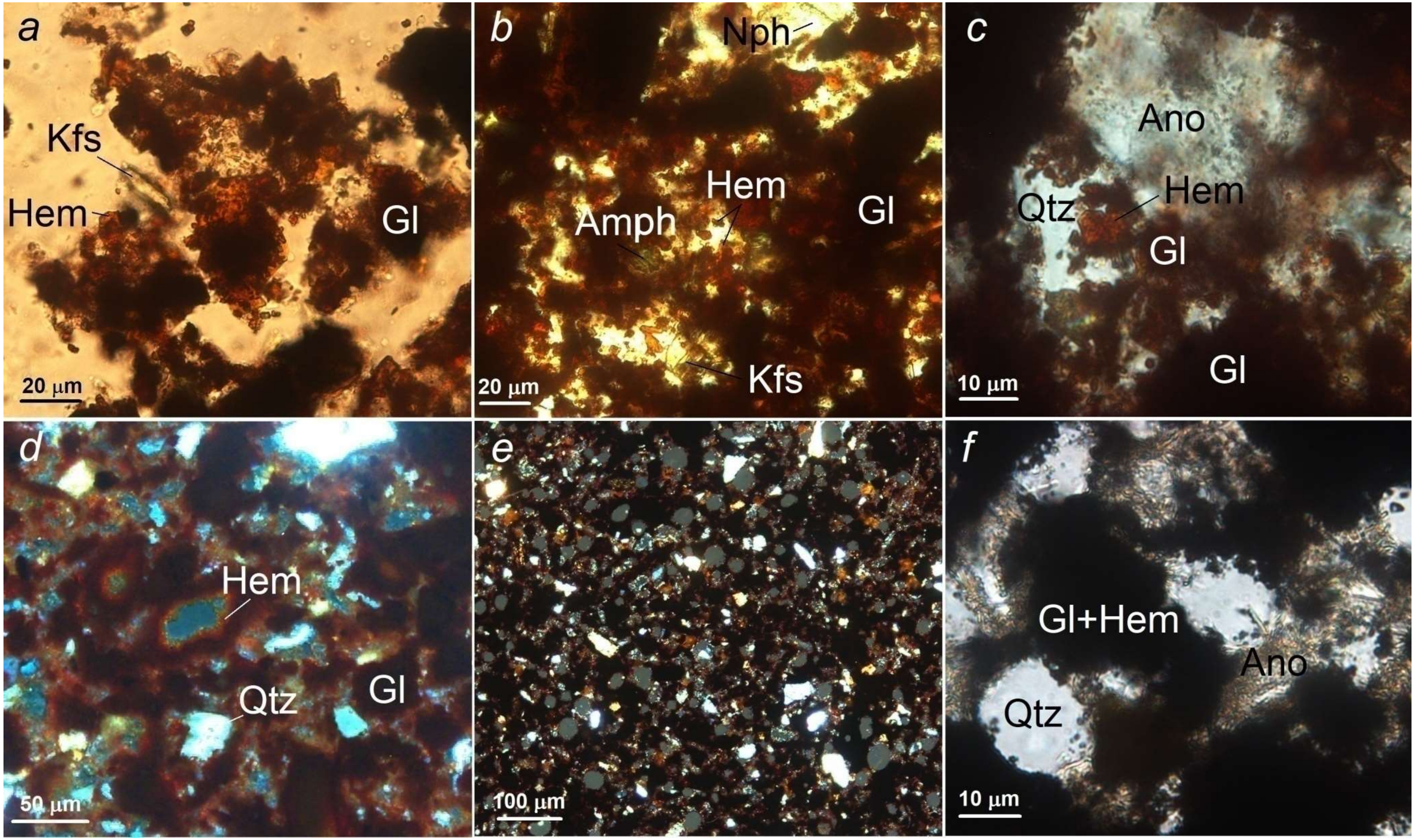
Component	Content, wt.%															
	SiO_2	Al_2O_3	FeO	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	SO_3	P_2O_5	NiO	MnO	SrO	CuO	LOI
CNS	40.11	-	23.26	12.00	13.24	-	1.04	0.50	0.71	0.68	-	0.14	0.11	-	0.06	0.06
ANT	40.95	21.17	2.63	5.85	1.19	6.01	10.13	5.85	2.53	-	2.20	-	0.27	0.22	-	1.00
FQT	63.31	4.16	2.16	20.84	3.22	3.71	1.00	0.75	0.12	0.10	0.10	-	0.13	-	-	0.40

Preparation of ceramic samples

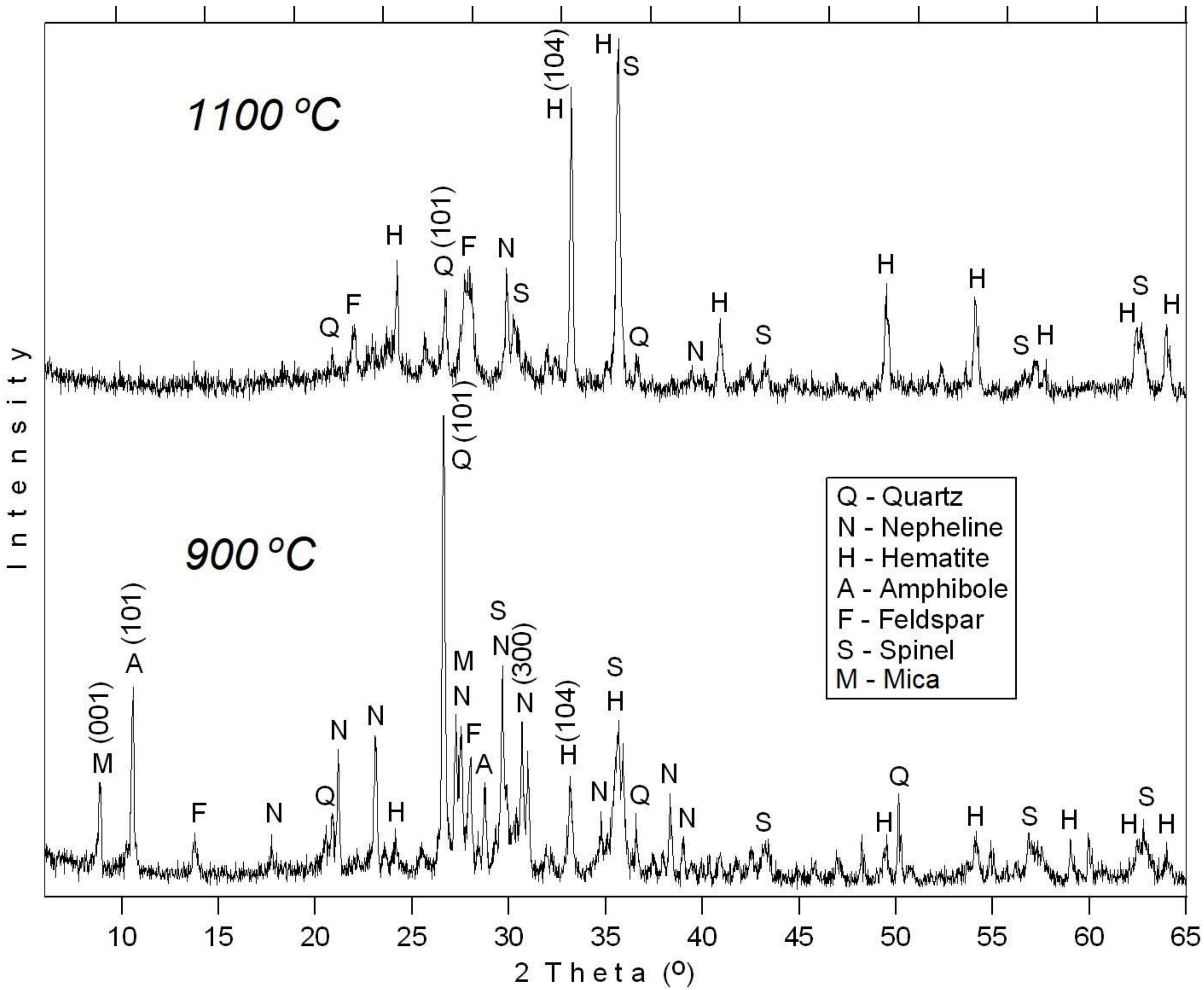
The feed materials were ground in a porcelain drum to the particle size of mesh 0.1 mm. The charge was carefully homogenized, wetted to achieve the optimal moisture content and molded at a forming pressure of 20, 50, and 100 MPa. The samples were dried at 105 ^{o}C and fired at 900, 950, 1000, 1050, and 1100 ^{o}C for 4 hours at the maximum temperature, followed by 1-hour isothermal exposure, temperature reduction to 500 ^{o}C at a rate of 2-3.5 ^{o}C/min and cooling in the furnace for 8 hours.

Testing of ceramic samples

[1] GOST 8462-85. Wall materials. Methods for determination of ultimate compressive and bending strength.
[2] GOST 7025-91. Ceramic and calcium silicate bricks and stones. Methods for water absorption and density determination and frost resistance control.
[3] GOST 27180-2001. Ceramic tiles. Test methods.

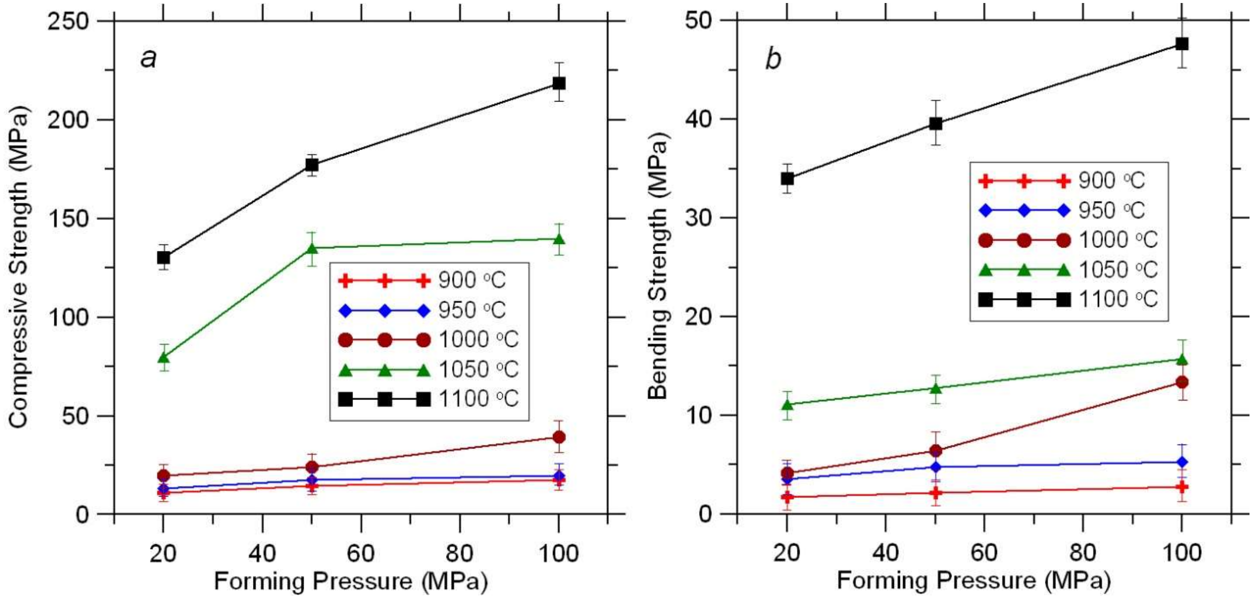


Photomicrographs of a ceramic sample. Crystallization of hematite plates in the sample as a result of firing at temperatures of 900 (a) and 950 °C (b). Replacement of quartz and nepheline with anorthoclase in the sample after firing at a temperature of 1000 °C (c). Cavitation (white arrow) surrounded by hematite plates as a result of firing at a temperature of 1050 °C (d). General view of the sample after firing at a temperature of 1100 °C (e). Grey – cavities, anorthoclase development when firing at a temperature of 1100 °C (f).

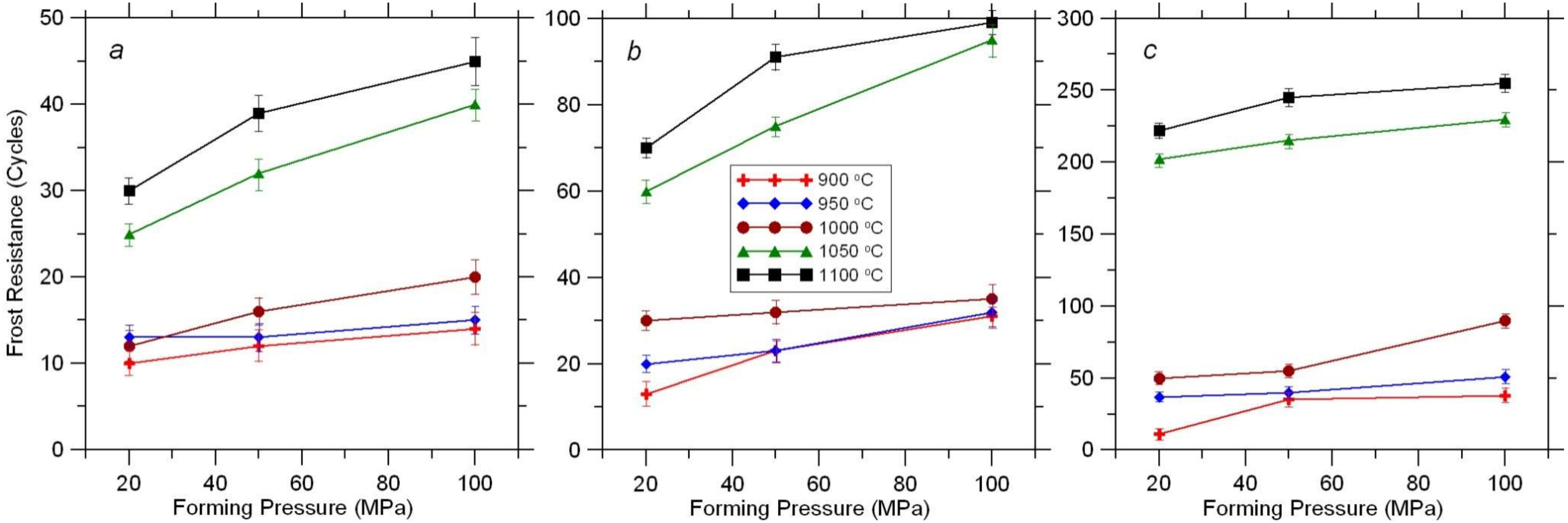


XRD patterns of a ceramic sample fired at 900 and 1100 °C.

Compressive and bending strength versus forming pressure at different firing temperatures



Variations in frost resistance versus forming pressure at different firing temperatures. (**a**)—Non-processed samples. (**b**)—Samples processed with water repellent. (**c**)—Samples processed with granular molding powders



Development of Methods for Treating Mine Waters

АО «КОЛЬСКАЯ ГМК»

Очистка шахтных вод рудника «Северный» АО «Кольская ГМК» методом электрохимической коагуляции

УДК 628.3:66.087.5

А. В. Светлов,
научный сотрудник лаб. экологии промышленного производства, канд. техн. наук, эл. почта: antonsvetlov@mail.ru

В. Г. Миненко,
ведущий научный сотрудник, канд. техн. наук, эл. почта: vladi200@mail.ru

А. Л. Самусев,
старший научный сотрудник, канд. техн. наук

Е. М. Салахов,
начальник бюро экологической безопасности

IMWA 2019 "Mine Water: Technological and Ecological Challenges"

Mine Waters of the Mining Enterprises of the Murmansk Region: Main Pollutants, Perspective Treatment Technologies

D. V. Makarov[1], A. V. Svetlov[1], A. A. Goryachev[1], V. A. Masloboev[1], V. G. Minenko[2], A. L. Samusev[2], E. A. Krasavtseva[1]

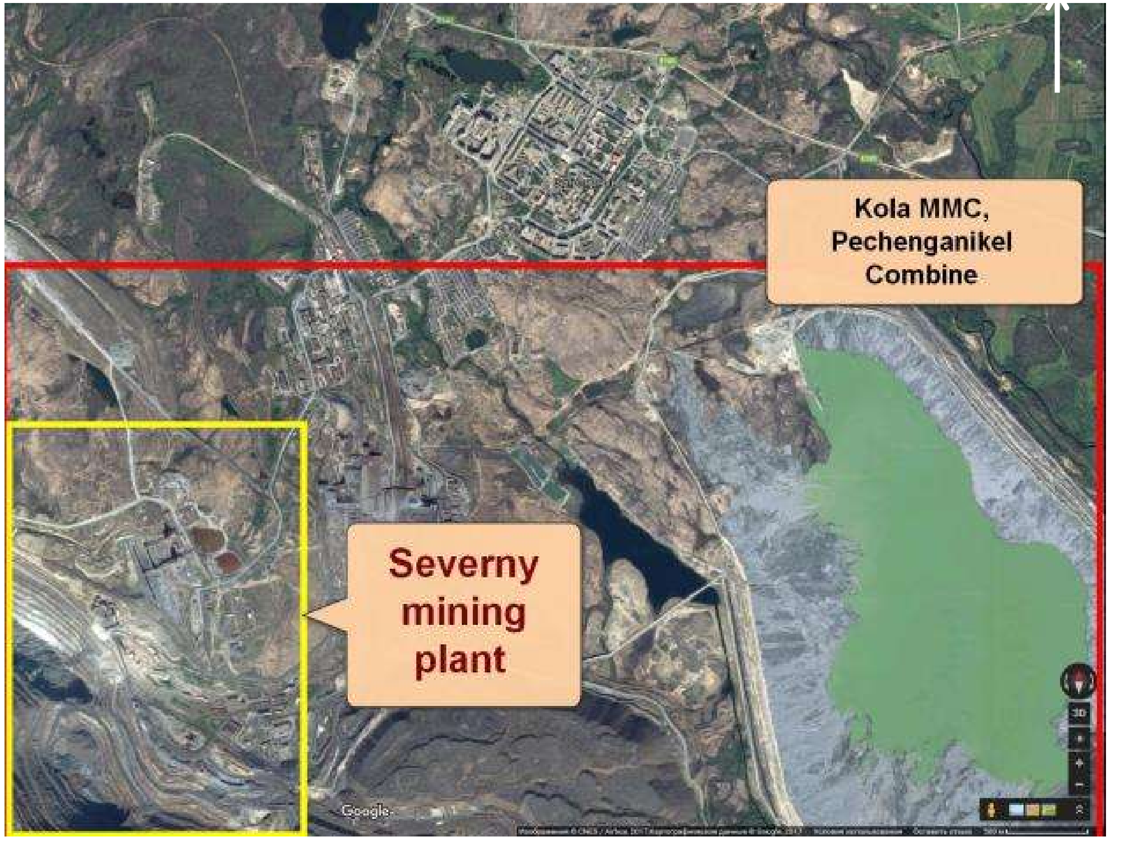
[1]Federal Research Centre "Kola Science Centre of RAS" Institute of Industrial Ecology Problems in the North, Apatity, Russia
[2]Institute of Comprehensive Exploitation of Mineral Resources of RAS, Moscow, Russia

Severny Mine, JSC Kola MMC

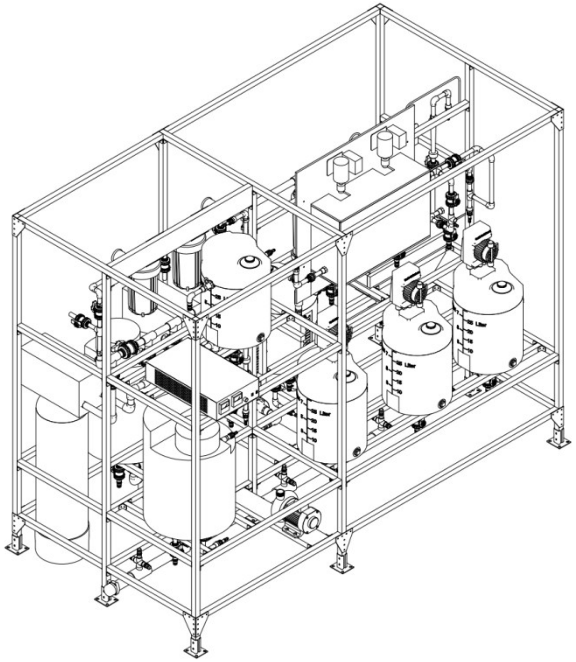
Main mine water pollutants

Color, grade	pH	Biochemical oxygen demand, mg/L	Suspended solids, mg/L	Ions, mg/L					
				NO_2^-	NO_3^-	NH_4^+	Fe	Ni^{2+}	Cu^{2+}
19	8	1.07	24.2	2.74	58.9	6.8	0.101	0.354	0.007

The daily mine water flow is nearly 28,000 m^3.



Pilot bench installation for water treatment



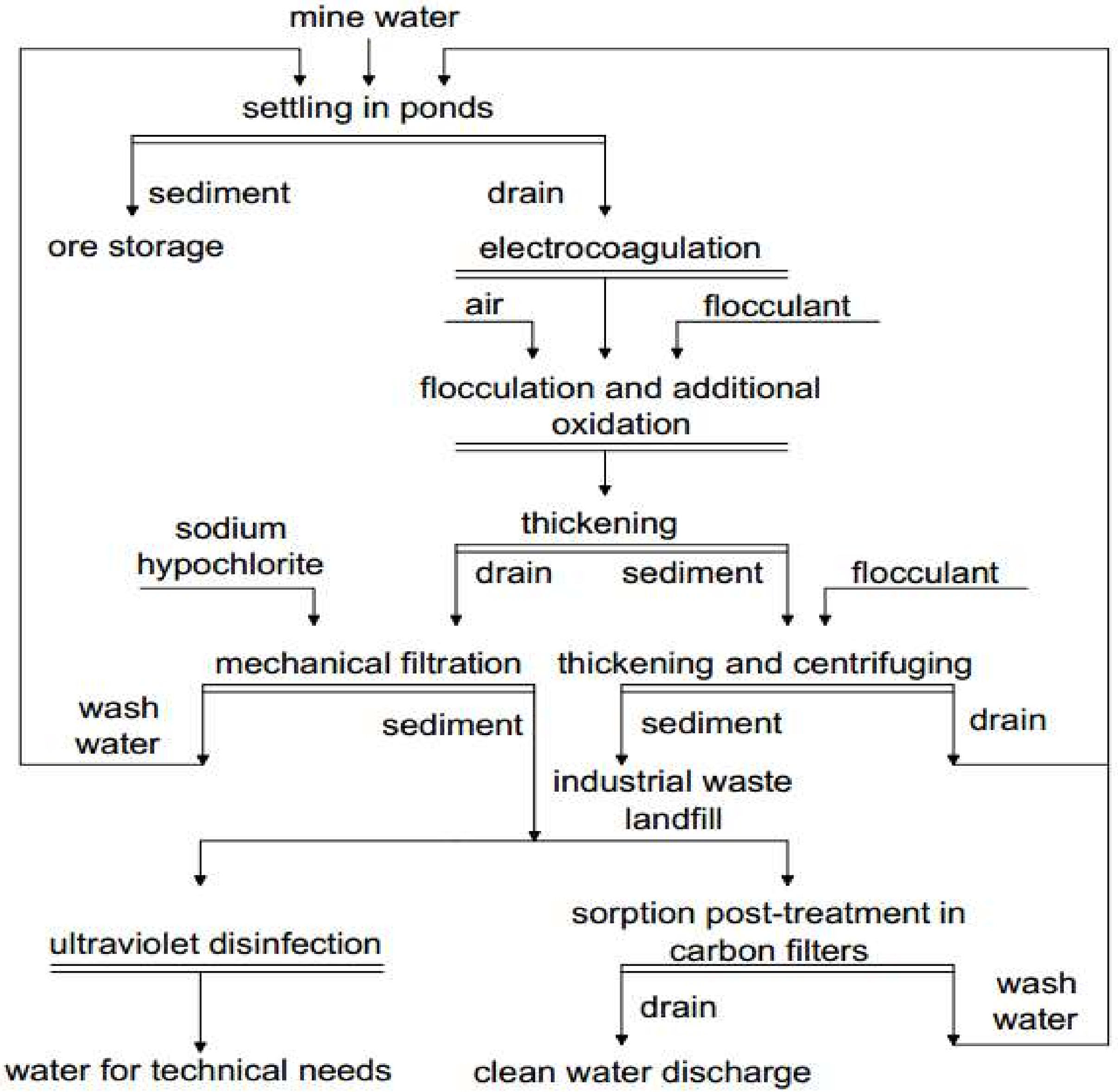
Chemical coagulation. Absence of sludge in grouped thickener

Sludge in grouped thickener after electrochemical coagulation

Selection of a mine water treatment strategy and process
Severny Mine, JSC Kola MMC

Comparison tests of technologies for purification of mine water at Severny Mine, JSC Kola MMC using chemical and electrochemical coagulation have been fulfilled. The advantages of electrocoagulation technology have been proved by experiment, which enables both the reduction of reagents use and higher level of water purification with the following components: copper, nickel, nitrogen compounds, suspended solids, coloration, biochemical oxygen demand, petroleum products.

Selection of a mine water treatment strategy and process
Severny Mine, JSC Kola MMC
Schematic diagram of mine water treatment



Industrial implementation of waste mine waters purification

- mechanical treatment of the input mine water to remove coarse particles by settling in ponds,
- electrochemical treatment (electrocoagulation using soluble electrodes of grade St.3 steel) of the clarified water,
- flocculation (formation of Fe^{2+} compounds) and additional oxidation of electrochemical coagulant (Fe^{2+} to Fe^{3+}) by air oxygen,
- coagulant settling in thin-layer sedimentation tanks (batch thickeners) with a selective feed of a flocculant in a wide range of pH values (5-10),
- mechanical filtration of the clarified water,
- sorption post-treatment in carbon filters,
- sediment collection and dewatering.

Selection of a mine water treatment strategy and process
Severny Mine, JSC Kola MMC

Sample name	Color, grade	pH	Biochemical oxygen demand, mg/L	Suspended solids, mg/L	Ions, mg/L					
					NO_2^-	NO_3^-	NH_4^+	Fe	Ni^{2+}	Cu^{2+}
Initial	19	8	1.07	24.2	2.74	58.9	6.8	0.101	0.354	0.007
After purification	<1	9	<0,5	2,9	0.187	0.163	1.26	<0.05	0.02	0.001
MPC	-	-	3	3	3.3	45	1.5	0.3	0.02	0.001

MPC - Maximum permissible concentrations of pollutants

Thanks a lot for your attention!