

IBRAE

Nuclear Safety Institute
Russian Academy of Sciences
(IBRAE RAN)

Final Report for activities under ANNEX 1 to the Project Arrangement between the Department of Energy (DOE) of the United States of America, and the Nuclear Safety Institute (NSI) of the Russian Federation for Coordination of Emergency Preparedness/Response Activities

Task 1

Conduction of scientific-technical works and organization of the general administration and scientific-technical support for the «Apatityvodokanal» (Apatity Water Utility) Pilot Project under the purview of the JCCRER

Milestone 3

“Analysis of Risks of Emergencies to Population and Territory, and Development of Measures to Reduce the Risks as applied to the «Apatityvodokanal» Utility”

**The REPORT is compiled under a subcontract with RUSSIAN CENTER
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EXECUTIVE SUMMARY

Background

The U.S. (Department of Energy) and Russia (EMERCOM and MINATOM), under the aegis of the Joint Coordinating Committee for Radiation Effects Research (JCCRER) and the Arctic Council's Emergency Prevention, Preparedness and Response working group are conducting a series of pilot projects to develop a risk assessment methodology / source control process for reducing the potential for emergencies at facilities handling radioactive or other hazardous materials. The projects include the development of a risk assessment methodologies document and on-site facility risk assessments at selected hazardous industrial facilities. The assessment includes the application of national technical and regulatory standards and the application of the international ISO 14001 Environmental Management Systems standard. The hazardous industrial facility selected for the first pilot project is the drinking water and sewage treatment utility in Apatity, Murmansk Region, Russian Federation. The facility handles 32 metric tonnes of liquid chlorine per year, with on site storage of 8-20 tonnes in 800-liter casks. A chlorine facility was chosen because of the wide spread use of chlorine in the nuclear and other industries and because international standards for the chemical industry are recognized worldwide. The second phase of this project will be at a MINATOM facility handling radioactive and/or nuclear materials. The initial pilot project produced two reports: *Risk Assessment Methodology at Hazardous Industrial Facilities (Working Draft)*, and *Analysis of Risks of Emergencies to Population and Territory, and Development of Measures to Reduce the Risks as Applied to the Apatityvodokanal Utility*.

Approach

Risk assessment at hazardous industrial facilities is an integral part of industrial safety management. Risk assessment is the systematic utilization of all available information to identify hazards and estimate risks of probable unexpected events. The

main goals of risk assessment are to provide company or facility decision-makers information on:

- the hazardous material within a facility and a rank order of the greatest to least potential risk/threat;
- identification and status of facility safety features, and
- reasonable recommendations to reduce the risk.

This information is used to prepare plans to mitigate incidents involving the hazards. In turn, decision-makers can use international standards and best practices such as the ISO 14001 process to establish prevention, preparedness and response programs based on relative risk and/or recommendations resulting from the effectiveness of systems and programs to manage the hazards. To these ends, agency management can establish a structure and programs to address these risks through the implementation of international or modified country-specific policies and programs that define objectives and targets to achieve end results. A critical outcome of the risk assessment process is to facilitate identification and implementation of corrective actions; planning and control. Of course, the audit and review of hazardous activities will be essential components to ensure that the environmental policy is complied with; and, that the environmental management system (EMS) remains appropriate to the risks identified and the program(s) to minimize those risks.

The primary report developed in this pilot project, *Risk Assessment Methodology at Hazardous Industrial Facilities (Working Draft)*, highlights three basic areas that are critical to an effective risk assessment. These are:

1. A thorough description of the risk assessment phases:
 - work planning and organization;
 - accident hazard identification:
 - a) hazardous chemical inventories, and
 - b) accidental hazards;
 - risk assessment; and
 - development of recommendations to reduce the risks.

2. A survey of the state of the art in risk assessment methods and criteria and appropriateness for the selection and application of these methodologies based on

available data, design criteria, and industrial operations.

3. Detailed documentation requirements.

A second phase of this project will be at a facility handling nuclear and/or radioactive materials. In preparation for and in carrying out a risk assessment for this facility, the risk assessment methodology document will be further adapted and refined as necessary.

This report is the implementation phase of the risk assessment methodologies to determine the physical and social aspects, and environmental impacts of the use of chlorine at the water treatment utility. This report presents findings of the risk assessment including measures to reduce risk, improve operational safety and enhance emergency prevention, preparedness, and response to hazardous chlorine processes and facilities. While assessing the risk, the typical accident scenarios, the reasons of their occurrence and the consequences were considered. Action item priority matrix (probability – consequence severity) was constructed to identify the most critical scenarios and due dates of performing the corrective actions.

Summary of Findings

In presenting the findings, this report describes the facility, the chlorine processes, the operating controls of the facility, facility safety management structure and procedures, safety training and devices, and emergency preparedness and response procedures. A risk assessment working group, (comprised of facility management and engineers, and technical experts from the Russian Chlorine Center and IBRAE), noted in the report that there had not been records regarding accidents and emergencies resulted in chlorine releases to the environment and personnel injury throughout the enterprise operation period. Experts identified five accident conditions and scenarios to explore and evaluate. Probabilistic characteristics of the concerned scenarios were obtained on the base of the operating experience analysis for the similar equipment at similar facilities in the former USSR and in Russia during 30 years. Risk reduction recommendations were

developed to "ensure reliable and safe operation of the chlorination plant in accordance with the requirements of regulatory requirements."

The report further recommends, consistent with the EMS process, that remedial measures should be implemented based on a comprehensive program. The program should include the following:

- Develop and implement system designs for emergency chlorine release absorption in sanitary columns at chlorine processing facilities.
- Provide reliable monitoring and control over chlorine flow conveyed for water decontamination and prevention of water ingress to chlorine pipelines of water chlorination process flow charts.
 - Develop a road-map for gradual replacement of valves installed at chlorine pipelines by those recommended by Gosgortekhnadzor of Russia.
 - Implement continuous remote control of chlorine weight in the cask (cylinder) during Cl₂ take-off by replacing mechanical scales by strain-gauge scale or meter.
 - Equip personnel of chlorination plant with protective suits to protect workers during emergency response.
 - [**] Install wheel guards at the storage facility to prevent vehicles from crossing the limiting line and run over the casks placed for storage.
 - [**] Equip cask transportation vehicles with special devices providing rigid fixture of the casks in the vehicle carriage body and their fixed position during transportation.
 - Implement psychological testing of personnel involved in operation of chlorination plant, chlorine transportation etc. for professional propriety according to the methodologies approved by Gosgortekhnadzor of Russia.

** The findings of the risk assessment described in this report clearly indicates that reducing the risk of damage to a liquid chlorine cask during transfer from rail car and truck transport poses "very high risk," is the highest priority and should be implemented as soon as practicable.

The risk assessment identifies that "events caused by erroneous [operational] actions of the service personnel," *human factors*, may be among the "main causes and factors" leading to serious accidents. The last three recommendations are aimed at the human elements of risk. Human factors causes and factors were not fully explored in the development and analysis of the "most typical accident scenarios." In the next project, human factors, including the adequacy of operational procedures and training will be more fully examined.

The Director of the Apatity water treatment utility participated in the risk assessment and the development of this report. In accordance with ISO 14001, site visits, meetings and the risk assessment are documented and included in this report. It is now up to the Apatity Utility management to carry out the next steps in the ISO 14001 process.

LIST OF EXECUTORS

From the Russia:

A.V. Steblov, Chief specialist, Russian Chlorine Safety Centre;

E.I. Kareva, Research worker, Russian Chlorine Safety Centre;

E.B. Hubih, Engineer, Russian Chlorine Safety Centre;

A.V. Shickin, Senior research worker, Nuclear Safety Institute of the Russian Academy of Science;

V.A. Norov, Director, GUP “Apatityvodokanal”;

A.A. Drozdov, Head of Production and Technical Division, GUP “Apatityvodokanal”

From the U.S.:

Bruce Russell, Director, JS&A Environmental Services, Inc.

INTRODUCTION

An increase in the amount and consumption of hazardous substances used in industry, more complex nature of the technologies and controls over modern processes require justified risk/safety assessments and criteria which take account of probability and consequences of possible accidents.

The detection of hazards and risk assessment are two prerequisites for development – in accordance with ISO 14001 requirements – of managerial plans to ensure environmentally safe conduct of operations. Detection of hazards is an intrinsic part of any existing management system. Risk is generally assessed through determining a probability of any hazards at facilities within the enterprise.

Application of the risk assessment at the enterprise assists in identification of a set of the most efficient measures to manage and prevent hazards present at the enterprise.

Figure 1 shows the stages to be pursued while compiling a Risk Management Plan.

This Report presents the measures to reduce risk, improve operational safety and emergency preparedness of the chlorination plant with the chlorine storage facility. These measures were developed based on the emergency risk analysis at GUP “Apatityvodokanal” enterprise.

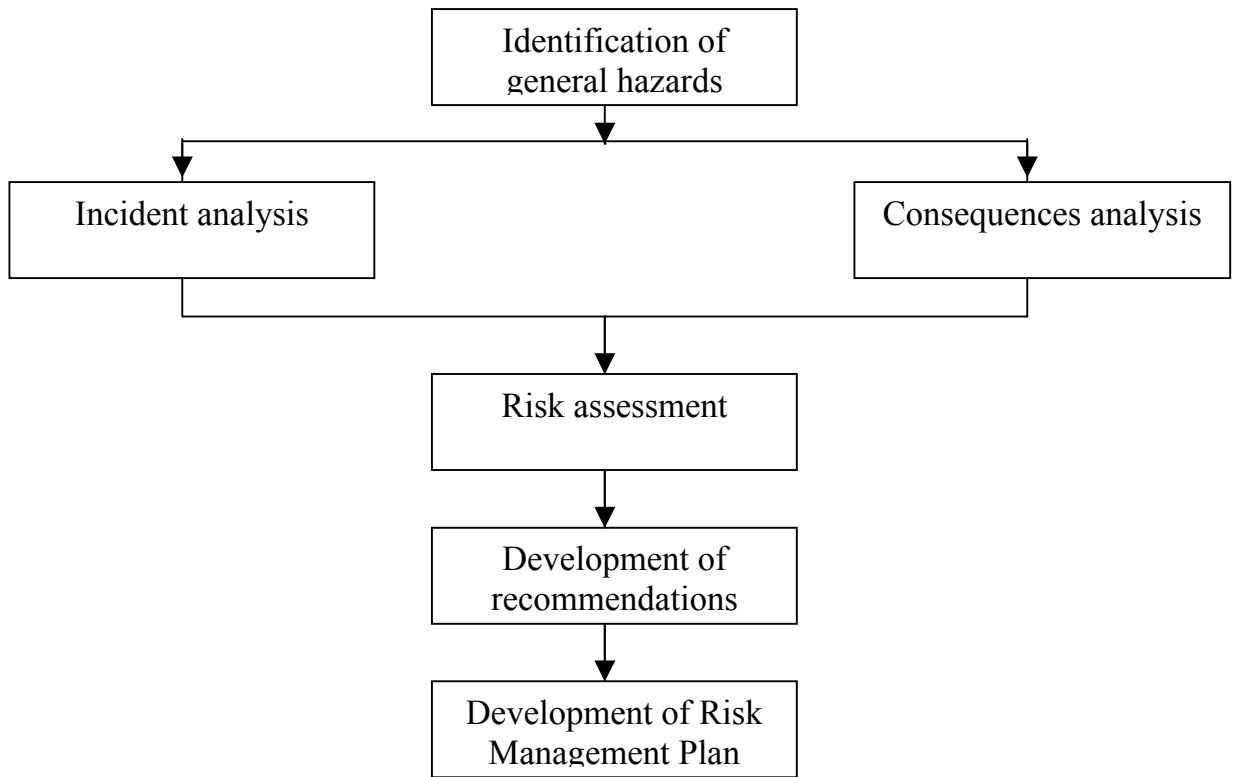


Fig.1. Main stages of generation of Risk Management Plan.

1 RISK ANALYSIS WORK GROUP

Accident risk analysis for hazardous industrial facilities (hereinafter referred to as “Risk Analysis”) is an intrinsic part of the industrial safety management. The Risk Analysis pursues a systematic use of all available information to identify hazards and assessment of risk of possible undesirable consequences.

The main tasks of the accident risk analysis for hazardous industrial facilities are to provide the decision-makers with:

- valid information on industrial safety level of the facility;
- information about the most hazardous, “weak” – in terms of safety - points; and
- justified recommendations on risk mitigation.

The special working group was set up to carry out the accident risk analysis for the potentially hazardous facility (PHF) GUP “Apatityvodokanal” and to study the hazard it poses and the level of its emergency preparedness. The group included:

- Norov V.A. – Director of GUP “Apatityvodokanal”;
- Drozdov A.A. – Head of Production and Technical Division;
- Androsik V.V. – Safety Engineer (responsible for in-house process control and monitoring at the facility);
- Shickin A.V. – Senior Researcher of IBRAE RAN; and
- Steblev A.V. – Chief Expert of the Russian Center “Chlorbezopasnost”.

The risk analysis work objective was:

- to examine and inspect whether the operating conditions of the potentially hazardous facility comply with the industrial safety requirements as described in the corresponding regulatory documentation;
- to update information on main hazards and risks;
- development of recommendations for organization of regulatory authority’s activities; and
- to improve the operating and maintenance procedures regarding the enhancement of industrial safety management system.

2 FACILITY DATA SUBJECT TO INSPECTION

Name: State unitary (affiliated) enterprise GUP "Apatityvodokanal", post address: 184200, Murmansk region, Apatity city, Vodoprovodnyi proezd, Appt. 1, tel. 6-24-25, fax 6-33-27, E-mail: vodokanal@aprec.ru.

It was established in 1977 to operate water supply and sewerage system of Apatity and Kirovsk cities. "Apatityvodokanal" is successor of Apatity Water Public Utility (WPU) of Murmansk region is registered by Apatity Administration by-law № 813 as of October 23, 1995. Umsk district of Tersk area was incorporated into WPU in 1981. This enterprise consists of industrial areas, water supply and sewerage system operation service, cold water supply and treatment structures, sewage treatment structures, water supply and sewerage networks, maintenance and repair services. Four hundred and thirty employees work for "Apatityvodokanal" as of December 1, 2002.

Structure and list of main services

Enterprise management:

- Accounts department.
- Customer department.
- Production engineering services.
- Procurement and warehouse department.
- Dispatcher service.
- Personnel department and registry.
- Occupational safety and health department.

Services:

WPU of Apatity area:

- Pumping water treatment plant buildings.
- Water supply and sewerage networks.
- Repair and engineering workshops.

Chief mechanical engineer service consists of:

- Motor transport area.
- Equipment centralized repair area.

Water quality testing center

- Chemical laboratory:
 - Drinking water control section;
 - Sewage monitoring section.
- Bacteriological laboratory.

To treat drinking water and sewage of treatment plants, liquid chlorine is utilized in accordance with the requirements of regulatory documents on water supply and sewerage system operation.

Chlorine-oriented enterprise services:

Chlorinating installation of Apatity water treatment and pump-house structures includes:

- Chlorine sub-store with heavy-lift and weighing equipment;
- Chlorinating installation;
- Air ventilation equipment; and
- Operating personnel premises.

Chlorinating installation of Apatity water treatment and pump-house structures is located on the territory of industrial junction being in-between neighboring areas of Apatity and nepheline plant № 2 (ANOF-2) of JSC "Apatit", Apatity heat power plant of JSC "Kolenergo," and Apatity-2 rail-way station. Its property is fenced and includes water supply facilities of GUP "Apatityvodokanal" and industrial water supply workshop of JSC "Apatit". (See plans on Fig. 2 and Fig. 3).

Chlorinating installation of Apatity water treatment and pump-house structures is 3 km away from population center of 62.6 thousand.

The maximum total number of shift personnel to be covered by chlorine hazardous contamination area of 500 meter radius (under severe accident, e.g. destruction of liquid chlorine cask of 0.8 m³) accounts for 203 individuals.

Scheme of Apatity Section of "Apatityvodokanal" Enterprise

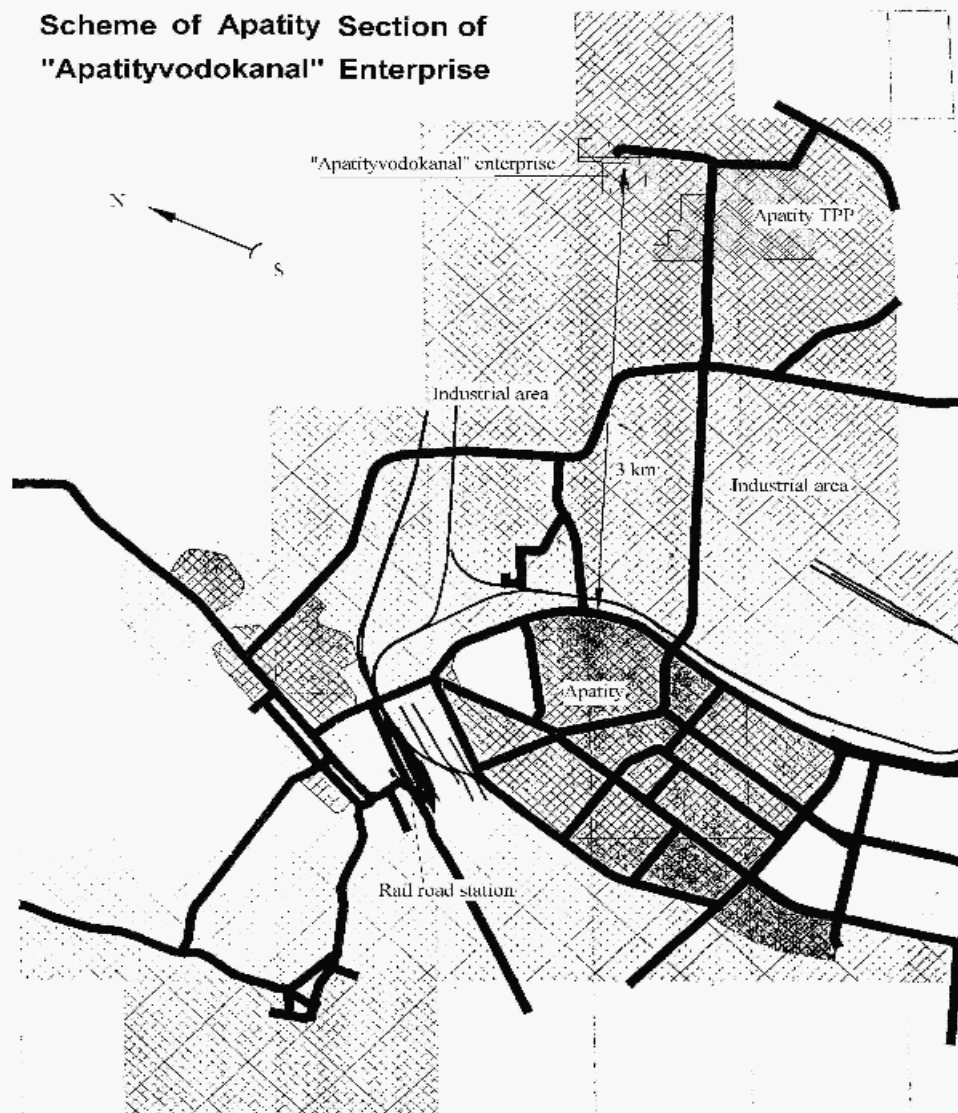
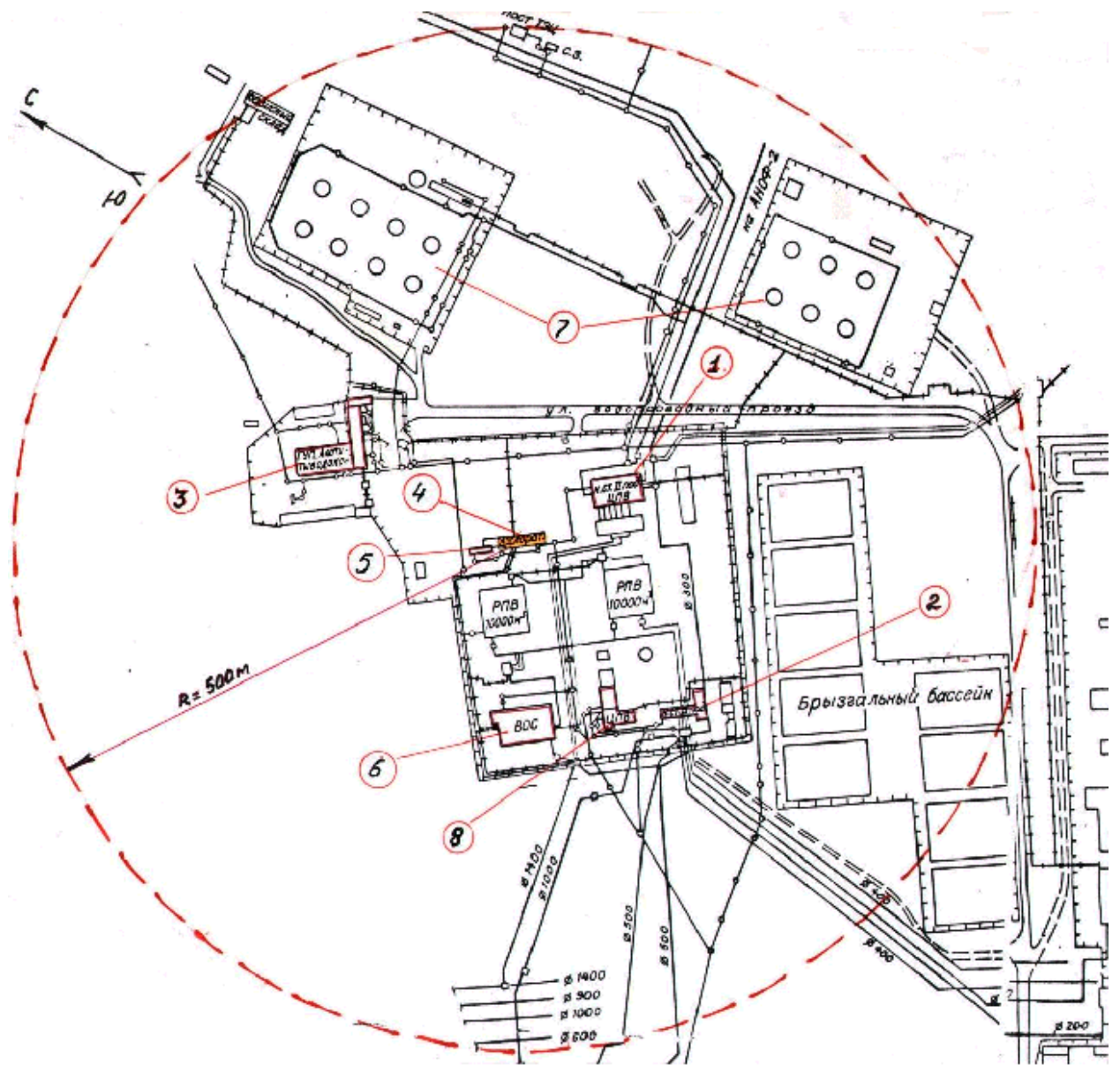


Fig 2. Scheme of "Apatityvodokanal" location (city of Apatity)



Item #	Facility	Maximum number of shift personnel at facilities (persons)
1.	Pumping station of JSC "Apatit"	3
2.	Pumping station of GUP "Apatityvodokanal"	1
3.	ABK GUP "Apatityvodokanal"	164
4.	Chlorination Plant of GUP "Apatityvodokanal"	3
5.	Water measurement Laboratory of GUP "Apatityvodokanal"	7
6.	Water Treatment Station of GUP "Apatityvodokanal"	3
7.	Mazout Storage Facility of JSC "Apatit"	4
8.	Service Water Supply Building of JSC "Apatit"	18

Fig.3. Schematic view of buildings and structures incorporated in the hazardous area pertaining to the Chlorination Station of GUP "Apatityvodokanal".

3 CHLORINE PROCESS

At GUP “Apatityvodokanal” the chlorine process includes the following main stages: liquid chlorine cask loading on trucks – transfer of the liquid chlorine cask to the chlorine storage facility – unloading of truck in the storage facility building – placing the casks on scales to take-off and supply chlorine for water chlorination.

In accordance with the agreement with JSC “Kaustic”, Volgograd, liquid chlorine is delivered in 800-liter casks by rail.

GUP “Apatityvodokanal” unloads the casks in its own dead-end track on a pad in accordance with the developed operations flow-chart.

Cask loading-unloading operations are carried out using the cask tilter, which allows to tilt the cask from horizontal into vertical position and vice versa.

The casks are transferred to the chlorine storage facility by trucks with an escort consisting of employees of the State Traffic Safety Inspectorate (GIBDD – road police) along the agreed transportation route.

Quantities of liquid chlorine sent to the chlorination plant warehouse at the water treatment plant of Apatity city are determined by a number of chlorine consumers incorporated into GUP "Apatityvodokanal". The list of chlorine consumers and chlorine distribution to GUP "Apatityvodokanal" facilities are presented below in Table 1.

Table 1.

Chlorine balance at GUP "Apatityvodokanal"

№	Chlorine balance	Treatment facilities, Kirovsk city	Treatment facilities, Apatity city	Water intake, Kirovsk city	Chlorination plant of water treatment plant	Umbsk area
1.	Chlorine quantities being concurrently stored, t	Up to 4	Up to 11	Up to 3	Up to 20	Up to 1
2.	Quantities of consumed chlorine: kg/h, t/yr	2.7 24	4.1-4.5 36-40	1.0 9.6	3.6 31.8	0.4 3.6
3.	Periodicity of supply	Once per quarter				

It is necessary to note that in accordance with Federal Law "On industrial safety of hazardous facilities" № 116-FZ as of July 20 1997 threshold chlorine quantity to be stored at an industrial facility which is classified as "Hazardous industrial facility" is 25 tonnes. Declaration on industrial safety is to be developed for such facilities. Chlorine quantities being concurrently stored at the facility in question do not exceed 20 tonnes. Therefore no such declaration is required.

Existing water chlorination process

A truck with casks enters – through the gates – the storage facility where the casks are unloaded from it using the tilter and then placed for storage and, eventually, on beam scale for chlorine take-off. The gaseous chlorine is taken-off from the casks-in-operation put on the beam scale in the storage room. Then gaseous chlorine is supplied from the sediment tank via the pipeline to the gaseous chlorine distributing header. Further, the agent (gaseous chlorine) is transferred to collector cylinders (interim cylinders) and then, through the rotameter, to the ejector where it is mixed up with water (see fig. 4). The flow-chart includes two chlorine tanks and two ejectors for chlorine dispensing, one being operative and the other – back-up. The parameter values and chlorine flow rate are maintained by the chlorination plant duty personnel.

Automatic gas analyzers are installed in the chlorination plant to detect presence of chlorine in the room. When chlorine alarm actuates the exhaust ventilation is triggered and the chlorine contaminated air is released into environment without clean-up because the facility does not have chlorine absorbers.

The chlorination plant of the pumping station is powered using Reliability Category 1 circuitry; i.e., from two independent power-supply sources.

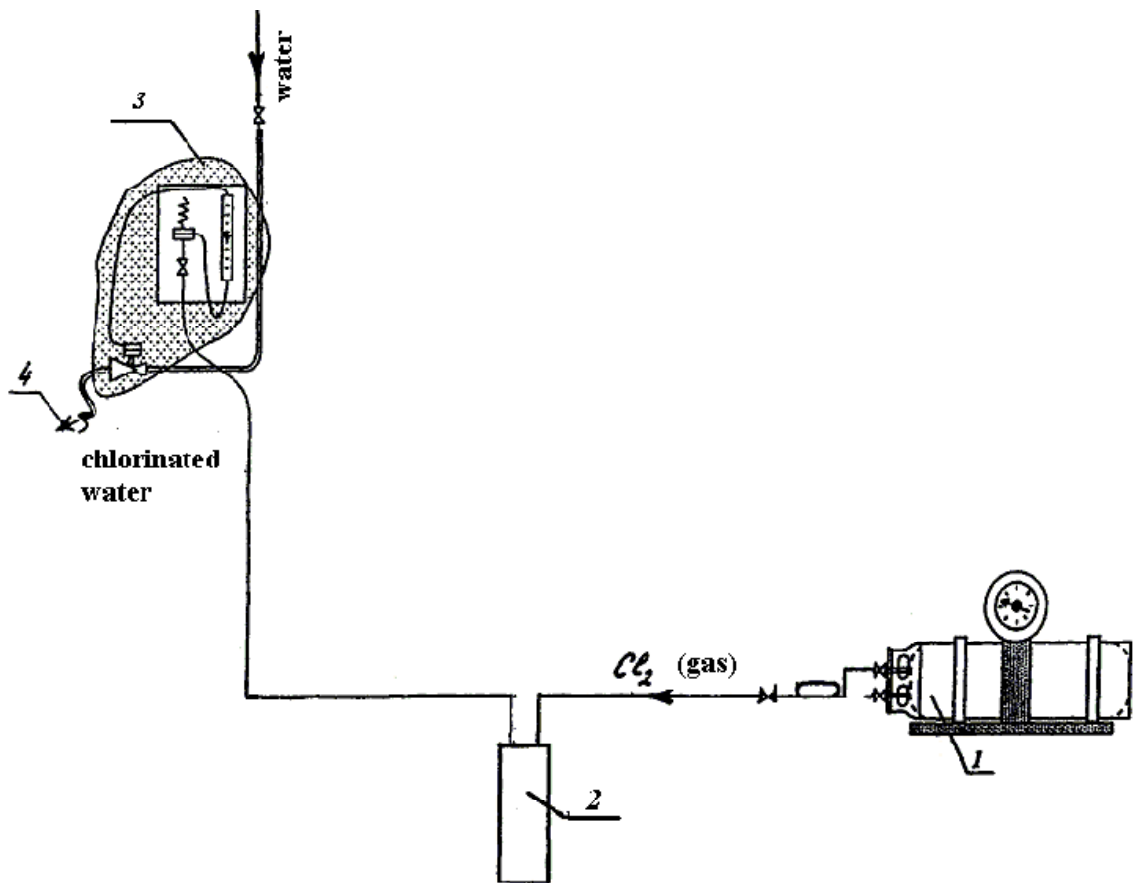


Fig.4. Process flow-chart of chlorine take-off for consumption:

1. Cask on beam scale
2. Sediment tank
3. Chlorinator (LONII-100K)
4. Chlorinated water supply

4 RESULTS OF THE EXPERTISE OBJECT STUDIES

The study of the chlorination plant along with the chlorine storage facility resulted in the following findings:

GUP “Apatityvodokanal” has in place an integrated system of organizational and technical measures, which includes safety monitoring, training of personnel, prevention of emergencies and accident consequences elimination.

The industrial facility features units and services, which structure and functions are targeted to safety insurance. These include the Industrial Supervision Division, Engineering Safety and Protection Division (ESPD), three Voluntary Gas Rescue Teams (VGRT), fire brigade and security guards.

The State Unitary Enterprise GUP “Apatityvodokanal” has implemented an operations control, which is an integral part of the industrial safety management system at the facility.

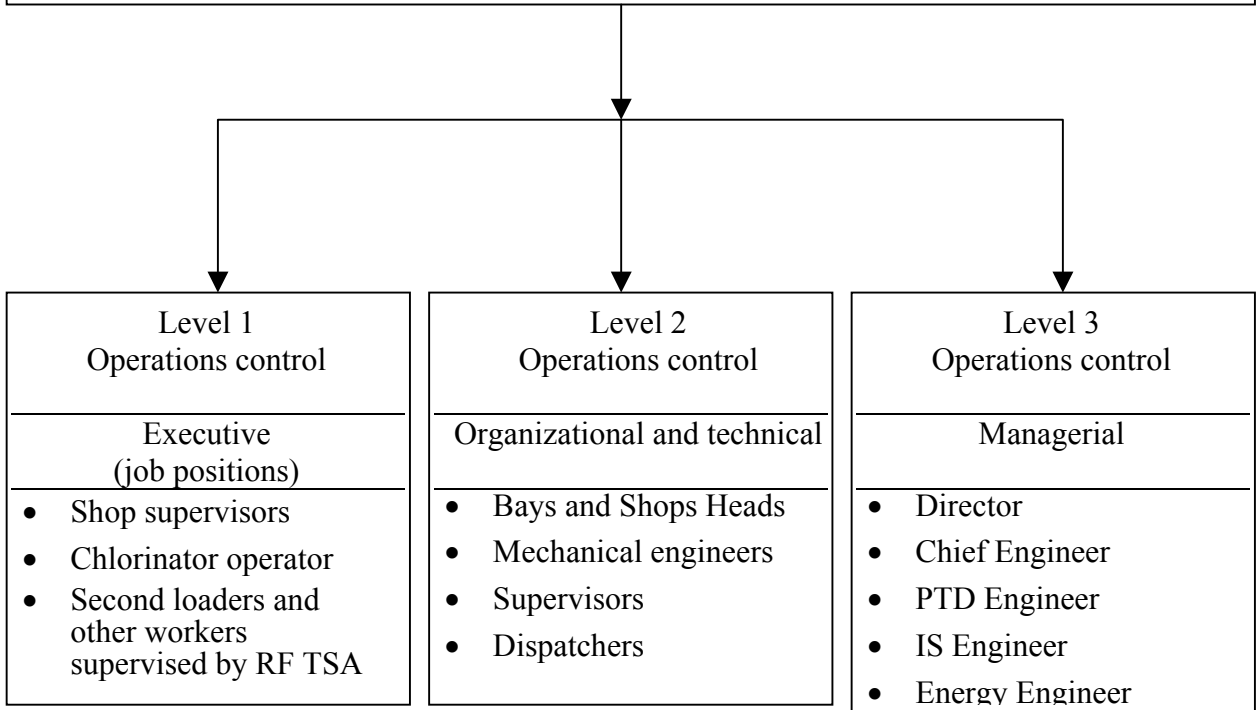
The main tasks of the operations control are:

- To ensure compliance with the industrial safety requirements for hazardous facilities of the enterprise;
- To analyze industrial safety level at hazardous facilities of the enterprise;
- To develop measures to improve industrial safety level and prevent damage to the environment;
- To supervise over compliance with the industrial safety requirements set forth by the Federal laws and other legal and regulatory and technical documents;
- To coordinate work to prevent accidents at the industrial facilities and to ensure preparedness for confining accidents and mitigating their consequences;
- To control over timeliness in term of necessary testing at the hazardous industrial facilities, repair and calibration of measurement instrumentation; and
- Control over compliance with the industrial discipline requirements.

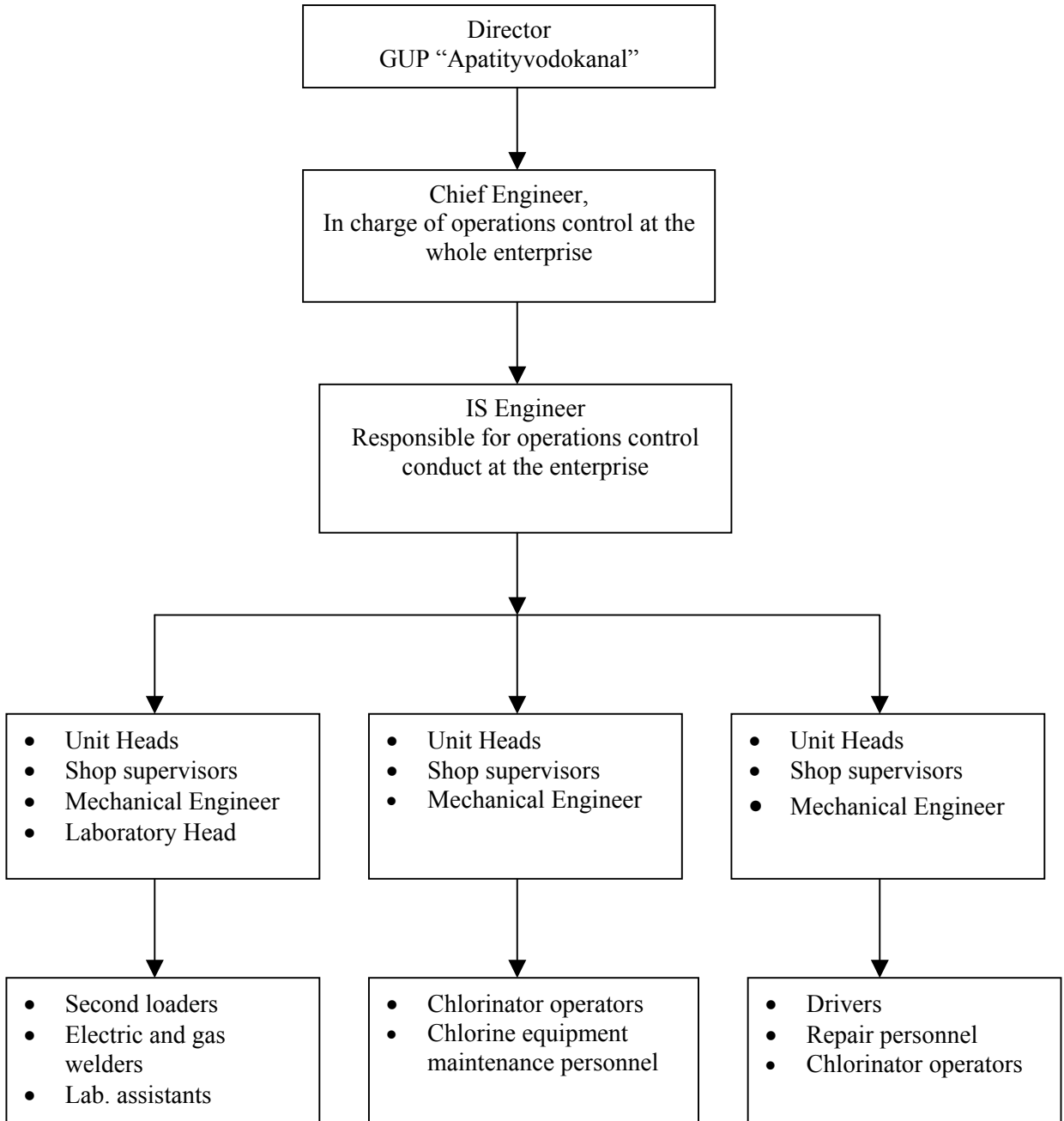
S Y S T E M
of industrial safety management (operations control)
at GUP “Apatityvodokanal”

Operations control:
 Implementation of a set of measures to ensure functioning of hazardous industrial facilities as well as to prevent accidents at such facilities and to ensure preparedness for confining of accidents and mitigating their consequences

1. Personnel and their qualifications.
2. Psychological support.
3. Technological support.
4. Technical support.
5. Safety insurance in emergency (abnormal) situations.
6. Power supply.
7. Materiel supplies.
8. Metrological support.
9. Environmental safety insurance.
10. Information, methodological and reference support.
11. Accounting of, analysis and assessment of industrial safety level.



Industrial safety management structure of
DUP “Apatityvodokanal”



In accordance with the Provisions for the Operations Control over compliance with the industrial safety requirements at hazardous industrial facilities of GUP “Apatityvodokanal”, the system of accident control and analysis has been organized to include:

- Daily (monthly) routine control to inspect whether the work conditions and conditions of equipment operation comply with the industrial safety requirements. The inspection results are entered into the Shift Transfer Log. The daily information on the inspection results is reported to the enterprise Management. Based on the inspection results and comments made by the regulatory authorities, the enterprise develops corresponding measures to eliminate identified violations and deviations from the requirements of the industrial safety standards and rules, and develops plans for their implementation.
- Targeted inspections at facilities (monthly).
- Comprehensive inspections at facilities: quarterly, semiannual, annual.

Additional information for analysis and considering incidents and accidents at hazardous industrial facilities as well as studying the operating experience and relevant recommendations are taken from periodic technical journals and publications:

- ◆ «Bezopasnost promyshlennosty» (industrial safety);
- ◆ «Grazhdanskaya zashita» (civil defense);
- ◆ «Biblioteka inzhenera po okhrane truda» (safety engineer’s library);
- ◆ «Okhrana truda i sotsialnoe strakhovanie» (protection of labor and social security).

The professional training of personnel is done for all categories of the enterprise employees in accordance with the legislation and safety-at-work standards, regulations on education and check of knowledge issued by the Ministry of the Russian Federation of Labor and Gosgortekhnadzor of Russia.

The professional training includes various briefings (entry, initial, recurrent, unscheduled, targeted), education and re-training of workers and check of knowledge of managers and engineers.

The employees acquire practical skills during annual educational and methodological seminars and exercises.

To improve operations safety at its facilities, GUP “Apatityvodokanal” develops, in concurrence with the federal authorized agencies, programs and plans of organizational and technical measures to bring up the industrial facilities in compliance with the requirements of applicable industrial safety standards and rules.

GUP “Apatityvodokanal” has developed preventive measures to protect hazardous industrial facilities, in particular, chlorination plant from terrorist attacks.

The facility has arranged for a strict visual examination of perimeter fence and continuous patrolling of the premises by the fast-deployment security force.

The fast-deployment security force are equipped with reliable communication means to contact the administration, FSS, MoI, MoE, FB.

The internal security force guards the chlorination plant on the shift basis.

The enterprise has obtained – in accordance with the established procedures – all necessary licenses to operate in the field of water treatment and sewage as well as environmental protection.

In particular:

- License to transport hazardous goods at a hazardous industrial facility;
- License to operate facilities associated with receipt, storage and use of chlorine;
- License to operate hazardous industrial facilities; and
- License to operate hoisting mechanisms, etc.

The operation of equipment, buildings and utilities of the water supply and sewage systems is carried out by the personnel trained and examined in the Operating Rules and Safety Rules for water supply and sewage systems.

The enterprise has developed the following instructions on safety-at-work during operation of chlorinating plants pertaining to GUP “Apatityvodokanal” to improve individual personnel qualifications:

- Instruction № 45 on safety during operating of the chlorination plant.
- Instruction № 32 on safety during repair of chlorine processing equipment.
- Instruction № 108 on safety for mechanicals operating devices to evacuate liquid chlorine from the affected cask.

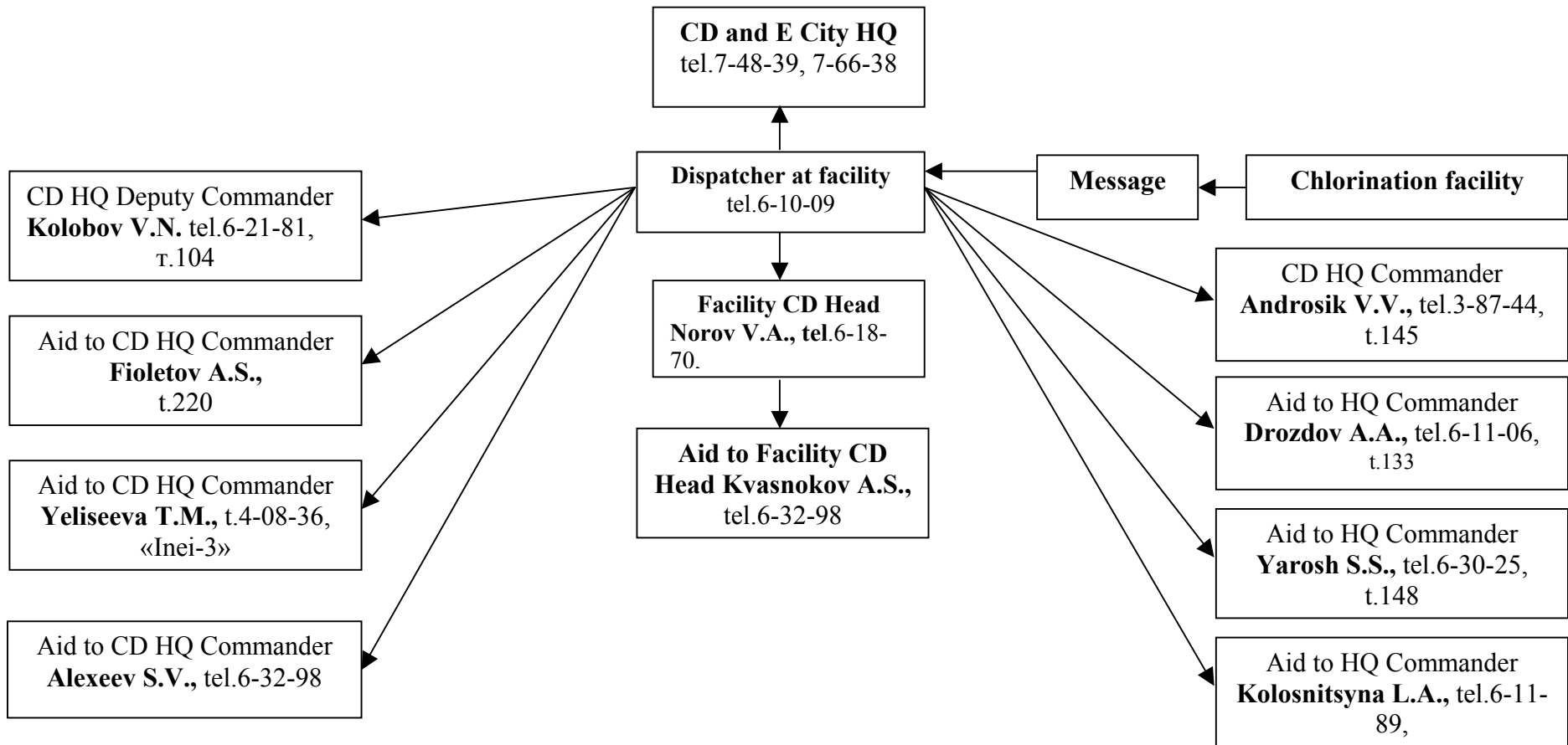
- Instruction № 105 on safety for workers operating in the area of possible exposure to chlorine.
- Instruction № 82 on safety during road transportation of strong poisonous agents.
- Instruction № 71 on safety during troubleshooting of the chlorination plant.
- Instruction № 70 on safety during storage of liquid chlorine.
- Instruction № 110 on safety during liquid chlorine shipments in casks by road.

GUP “Apatityvodokanal” has coverage under a civil liability insurance policy for organizations operating hazardous industrial facilities for the amount of 80,540 rubles.

In emergencies, the enterprise’s rescue team operates jointly with the Civil Defense and Emergency Headquarter (EMERCOM) of the city.

The enterprise has developed a plan for confining and eliminating accidents involving chlorine releases, fire, loss of power and water supply at the chlorine processing facilities of GUP “Apatityvodokanal”. The following is a notification diagram for the GUP “Apatityvodokanal” personnel in case of emergency in working hours at the facility. Work schedule of dispatcher service of the facility and operative men on duty of CD and E city HQ covers 24 hour a day. In after working hours, the notification diagram is the same. The only difference in the notification procedure is that for after working hours home addresses and telephone numbers are used instead of office ones.

Notification of Managers and Commanding Personnel of GUP “Apatityvodokanal” in working hours in case of contingency



The Command Post (Headquarters) is located in the Enterprise Dispatcher Office
The HQ personnel is gathered by loudspeaker messages; in case of contingency – at the audible alarm signal

The enterprise has concluded an agreement with a specialized organization for providing information and consultant services regarding industrial safety issues, organization of operations control, and training and qualification of GUP “Apatityvodokanal”

The enterprise lacks adequate personal protective equipments to protect respiratory organs and skin from 100% gaseous chlorine and local exposures to liquid chlorine. This prevents from prompt confining of an accident involving release of chlorine from process equipment and pipelines.

The chlorination plant with storage facility lacks an adequate emergency chlorine release absorption system. This does not allow for efficient confining of an accident at the facility in case of loss of integrity or collapse of chlorine containing process equipment and causes significant damage to the environment.

At the enterprise the process parameter monitoring regarding chlorine consumption is done visually and the control is done manually. This is not in accordance with the requirements of para. 4.1 и 4.15 of the Safety Rules for production, storage, transportation and use of chlorine. (PB 09-322-99).

Chlorinators LONII 100K are used for dispersion of gaseous chlorine and mixing it with water in chlorination plants. Gosgortekhnadzor of Russia does not permit these devices for application (requirement of para1.5, Rules PB 09-322-99). This is due to the fact that the design solution of the reducing valve (gate) and the check valve of the LONII 100K chlorinator’s ejector do not ensure reliable functioning. There are multiple cases of water ingress from ejectors into chlorine piping during operation of these chlorinators.

The beam scale RP-3Sh13M used at the chlorination plants does not allow for continuous remote monitoring of chlorine flow rate and drainage of the tank (cylinder) – requirement of para. 4.1 and 9.3.13, Rules PB 09-322-99.

The cut-off fittings installed at chlorine pipelines are not covered by a permit issued by Gosgortekhnadzor of Russia for their application at the chlorine processing facilities; this disagrees with the requirements of para. 1.5, Rules PB 09-322-99.

After have being placed in the truck body the chlorine casks are not anchored with chains on the rack, which would ensure secure stowage of the casks during transport.

The chlorine storage facility lacks wheel guards that would prevent a truck from passing through the limiting line that may cause the head-on crush to the casks in the chlorine storage facility, their collapse and chlorine release into the environment.

5 RISK ANALYSIS AND ASSESSMENT

5.1 Analysis of accident initiation and development conditions

Chlorination plant of GUP “Apatityvodokanal” is one of the typical smaller water treatment facilities in common use in Russia and constructed in accordance with standard designs of 901-3-14/70 series “Chlorination plants with capacity of 5-50 kg/hour combined with chlorine service storage facility” and developed by Central Scientific and Research Institute of Experimental Design in 1970. The number of such facilities in Russia exceeds 7 000. By now technical solutions implemented in the designs of this series are outdated and don’t meet the requirements of existing regulatory and technical documentation as specified in Section 4 of this report.

According to GUP “Apatityvodokanal” there are no records regarding accidents and emergencies resulted in chlorine releases to the environment and personnel injury since 1977 when this chlorination plant and storage facility were put into operation.

However, analysis of emergencies conducted by Chemical Safety Engineering Institute involving data base for the accidents occurred both in our country and abroad demonstrates that accidents resulted in chlorine releases to the environment are possible at the facilities similar to GUP “Apatityvodokanal” being under consideration. Toxic exposure of individuals and chemical contamination of the environment by chlorine being extremely hazardous substance of acute suffocating are the most hazardous in case of such accidents. Chlorine characteristics are presented below in table 2.

Table 2

Characteristics of hazardous substance

N	Parameter items	Parameter	Source of information
1	2	3	4
1.	<i>Substance name</i>	Chlorine	[1]
1.1	Chemical		
1.2	Trade	Liquid chlorine. Extra class OKP 20 1431 0120	
2.	<i>Formula</i>		

N	Parameter items	Parameter	Source of information
2.1	Empirical	Cl ₂	[1]
2.2	Structural	Cl-Cl	[2]
3.	<i>Composition, %</i>		[1]
3.1	Main product - mass fracture of main product, not less than	99.8	
3.2	Impurities (with identification) - mass fracture of water, not more than	0.1	
	- mass fracture of nitrogen trichloride, not more than	0.002	
	- mass fracture of nonvolatile residue, not more than	0.015	
4.	<i>General data</i>		[3]
4.1.	Molecular weight	70.90	
4.2.	Boiling temperature, °C (under pressure of 101 kPa)	-34.06	
4.3.	Density at 20°C, kg/m ³	3.214 (gas), 1500 (liquid)	
5.	<i>Data on explosion and fire hazard</i>	Nonflammable, but sustain combustion of many organic substances.	[3,4]
5.1.	Ignition temperature	Turpentine и metal powders ignite spontaneously in chlorine medium at room temperature	
5.2.	Self-ignition temperature		
5.3.	Explosibility limits		
6.	<i>Data on toxic hazard</i>		[3, 5, 6]
6.1.	PLC in the working bay air	1 mg/m ³	
6.2.	PLC in the atmosphere	Maximum, single –0.1 mg/m ³ Daily average – 0.03 mg/m ³	
6.3.	Lethal toxic dose LCI ₅₀	$6 \frac{\text{мг} \cdot \text{мин}}{\text{л}}$	
6.4.	Threshold toxic dose PCI ₅₀	$0.6 \frac{\text{мг} \cdot \text{мин}}{\text{л}}$	
7.	<i>Reactivity</i>	Reactive, active oxidizing agent	[1, 3]
8.	<i>Odor</i>	Strong, specific	[3, 4]
9.	<i>Corrosion impact</i>	At temperature up to 100°C dry chlorine (humidity not > 0.04% weight) practically does not interact with carbon and low-alloyed steels used for fabrication of the equipment operated in chlorine medium. Interaction of dry chlorine with titanium leads to	[3]

N	Parameter items	Parameter	Source of information
		its self-ignition even at the temperature of 30°C. Titanium does not interact with wet chlorine (humidity > 0.04% weight) at the temperature up to 100°C.	
10.	<i>Precautions</i>	While dealing with chlorine it is required to use individual protective means to protect respiratory organs and skin.	[1, 3]
11.	<i>Impact to individuals</i>	Chlorine irritates throat if concentration is $\geq 45 \text{ mg/m}^3$, causes cough if concentration is $\geq 90 \text{ mg/m}^3$, chlorine concentration of $> 3000 \text{ mg/m}^3$ causes death at several breathings-in. Chlorine affects lung tissue and causes lung oedema; If skin is affected it leads to acute dermatitis.	[3]
12.	<i>Protective means</i>	Chemical protective suits, rubber gloves and shoes.	
13.	<i>Techniques to convert substance into harmless state</i>	Collecting and neutralization by 10-20% solution of sodium hydroxide resulted in sodium hypochlorite	[3]

N	Parameter items	Parameter	Source of information
14.	First aid measures for individuals injured by the substance	<p>In case of chlorine poisoning release the injured from smothering clothes, provide still and quiet conditions, heating, conduct inhalation by wet oxygen using GS-10 apparatus.</p> <p>For irritated upper respiratory tracts – inhalation by dispersed alkaline solutions of soda bicarbonate; eye, nose and mouth washout by 2% solution of soda bicarbonate.</p> <p>Plenteous drink (warm milk, milk with borjomi (mineral water) or soda, coffee).</p> <p>If there are no evidences of breath conduct kiss of life or use GS-10 apparatus.</p>	[1]

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1. GOST 6718-93. Liquid chlorine. Technical conditions.
2. M.Kh. Karapetyants, S.I. Drakin. Substance structure. M.:“Vysshaya shkola”, 1970.
3. A.F. Timofeev, B.Yu. Yagud. “Safety engineering during chlorine storage, transportation and application” M.: “Printer”, 1996, 519 p.
4. Fire safety of substances and materials used in chemical industry. Manual. Under the editorship of I.V. Ryabov. M.: “Khimiya”, 1970, 336 p.
5. GOST 12.1.005-88. General sanitary and hygienic requirements to the working bay air. M.: “Standarty”, 1988.
6. Permissible limited concentrations (PLC) of hazardous substances in the working bay air. GN 2.2.5.686-98. Minzdrav Rossii. M.: 1998.

Main causes and factors facilitating accident initiation and development accidents

At the chloride storage facility belonging to GUP “Apatityvodokanal” the accidents involving chlorine releases into the environment may occur due to several causes (or their combination), which can be divided into two groups:

- ◆ Operations induced causes.
- ◆ External impacts:
 - of technological nature (operation of neighboring enterprises);
 - natural impacts (hurricanes, earthquakes); and
 - acts of sabotage.

The operations induced causes include:

- ◆ Hazards related to a mechanical damage to containers during their unloading from open wagons; transfer to storage bays; and from the storage bays for loading onto motor vehicles for shipment to the chlorine consumers.
- ◆ Loss of integrity of a container (shell, valves, flanges), pipeline due to corrosion, mechanical damages, physical wear.
- ◆ Degrading of a container shell due to a chlorine overflow at the filling plant or ingress (at the filling plant) into the container of alien substances chemically active with chlorine (water, hydrocarbons, etc.).
- ◆ Unavailability or disruption in the power supply may lead to termination of the operation of automatic gas analyzers, switch off of alarms, and emergency protection systems. It should be noted that the coincidence of loss of power and chlorine leak from a container would lead to chlorine releases beyond the chlorine storage facility barriers into the environment because of the emergency ventilation system failures. In addition, the absence of a chlorine neutralization system in the sanitary columns would lead to exposure of people to chlorine and damage to the environment.
- ◆ Events caused by erroneous actions of the service personnel or by failures of process parameter monitoring and control means as well as the emergency protection systems.
- ◆ Errors made in the course of design of chlorine storage facilities, in particular, absorption columns may lead to chlorine effluents to the environment due to a low efficiency of the absorbers.

Technological external impacts:

In the close vicinity of the chlorine storage facility there are no potentially hazardous facilities (storages of explosives and toxic substances, gas-filling stations, oil pipelines, etc.) at which accidents may pose danger to the chlorine storage facility belonging to GUP “Apatityvodokanal” and interfere with normal operations at the facility.

Natural external impacts:

Such natural phenomena as showers, hail, and snow cannot lead to loss of integrity of containers stored in the storage bays and release of chlorine to the environment.

Tornadoes, hurricanes can damage the roof of the chlorine storage building but it is unlikely that they cause damage to the building load-bearing structure and eventual loss of container integrity.

Lightning or its secondary effects can lead to situations similar to those induced by loss of power.

The industrial site location excludes a possibility for such phenomena as mudflows, avalanches, tsunamis, sinks, etc. to occur.

Acts of sabotage are highly unlikely at the declared facility due to a multi-level intrusion prevention system protecting the chlorine storage facility from unauthorized individuals.

Possible Accident Scenarios

The following cases of emergency loss of integrity are possible at the liquid chlorine storage facility:

- chlorine leaks through loose valves or corrosion holes and macro-cracks in the vessel shell;
- chlorine leaks through loose joints between a flange with shell or container valve;
- chlorine releases through container shell breaks, etc.

In the schematic below there are possible accident initiating and stage-by-stage development scenarios.

Each accident may be mitigated, develop into the next stage of an accident that is under control or expand to a higher level before the accident is under control.

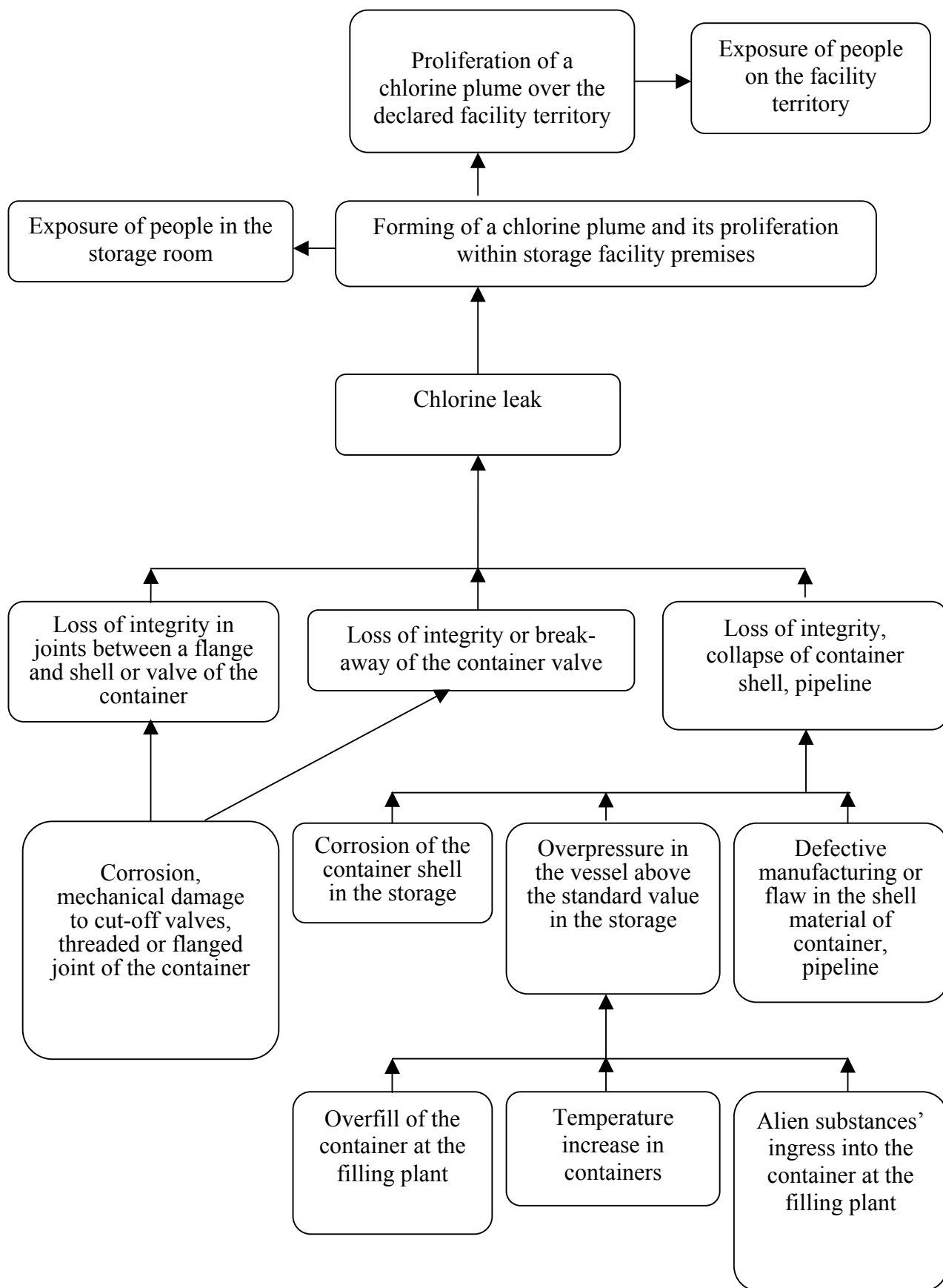
At the storage facilities where chlorine is stored in containers the accidents develop, generally, as follows: loss of integrity or collapse of the container, receiver (device for smoothing of chlorine pressure pulsations in a chlorine pipeline), pipeline → chlorine release → forming and proliferation of a chlorine plume within premises and in the open → exposure of people present in the chlorine storage rooms and in the open.

Based on the results of GUP "Apatityvodokanal" examination, the working group has reviewed the most hazardous emergency scenarios (in terms of consequences) and some of the most probable accident scenarios to conduct risk assessment. The goal of this review was to verify effectiveness of the methodology developed during phase 1 of this project and identify measures to reduce the risk of an accident to acceptable level.

The following most typical accident scenarios, categorized depending on chlorine release conditions, were studied to assess danger and consequences of a chlorine release at the storage facility:

- Scenario C₁ – collapse of a container (with release of whole chlorine content) due to its overflow or mechanical damage during loading, unloading and transfer.
- Scenario C₂ – break-away of the container valve communicating with the liquid phase (release of liquid chlorine) due to a mechanical damage during loading and unloading operations as well as due to corrosion.
- Scenario C₃ – break-away of the container valve communicating with the gaseous phase (release of gaseous chlorine) due to the causes indicated in Scenario C₂.
- Scenario C₄ – loss of integrity of the container shell, pipeline due to corrosion induced by water ingress into the equipment (chlorine leak through a hole of equivalent diameter 0.3 to 2mm).
- Scenario C₅ – loss of integrity of the container cut-off valves or locations where it is connected with the container shell due to corrosion, sealing defects, etc. (chlorine leaks through a hole with equivalent diameter 0.3 to 2mm).

Possible scenarios for initiating and developing of accidents at the liquid chlorine container storage facility belonging to GUP "Apatityvodokanal"



When a container, pipeline containing liquid chlorine loses integrity a part of the leaked chlorine “instantly” evaporates and the remaining part is cooled down to a temperature corresponding to the chlorine boiling temperature (at pressure approximately equal to the ambient one). The amount of “instantly” evaporating chlorine is determined by the amount of its inherent energy and substantially depends on the liquid chlorine temperature. In addition to the “instantly” evaporating chlorine the pool resulting from liquid chlorine leak is a gas release source due to the fact that evaporation from this pool takes place because of its heat exchange with the storage facility floor or soil. In addition a gaseous chlorine release from the container is possible. The amount of released chlorine depends on the area of the opening that is forming, aggregate state of chlorine, pressure in the vessel, leak elimination time and amount of the hazardous substance in the container.

Depending on the accident scenario to be studied, functions describing the rate of chlorine leakage are different. So for the gaseous chlorine leak the linear leak rate is described by a polytropic equation. In case of the liquid chlorine leak the leak rate is expressed by the known Bernoulli equation.

5.2 Assessment of hazardous substance amount involved in the accident

Scenario C₁. Collapse of a liquid chloride container. When such accident occurs, up to 1000 kg of chlorine may be released into the environment. The process of gaseous chlorine release due to a container collapse may be represented as the following sequential stages: instant chlorine evaporation and boiling of the “cooled” chlorine pool formed during the release.

The instant evaporation of chlorine is characterized by a fast – within several seconds – transition to the gaseous state up to 20%, i.e. up to 200 kg of liquid chlorine (at the initial temperature of chlorine in the container 25⁰C).

The remaining part of liquid chlorine will be cooled down to its boiling temperature at the ambient pressure and will boil due to heat transfer from the contact surface. The specific capacity of this gaseous chlorine source is 1.7 g/s·m² (Data from SNiP 2.04.02-84* “Water Supply. External Lines and Structures”), which in case of unobstructed chlorine leak will be about 180 g/s.

Scenario C₂. Break-away of the container valve ($d_e \leq 15$ mm) communicating with liquid chlorine.

In case of this accident the amount of resulted gaseous chlorine G is composed of two constituents: G' и G''

G' - is the amount of instantly evaporating chlorine (at the expense of heat of superheat accumulated in it, which depends on chlorine temperature in the vessel at 25°C. It is about 20% the liquid chlorine released, i.e. 1.25 kg/s.

Recalculation to the gaseous chlorine gives $G' \cong 1500 \text{ m}^3/\text{hr}$.

G'' is the amount of gaseous chlorine resulted from the leak of liquid chlorine. In case of an unobstructed leak it is 180 g/s.

Thus,

$$G = G' + G'' \cong 1.5 \text{ kg/s}$$

Scenario C₃. Break-away of the container valve ($d_e \leq 15$ mm) communicating with gaseous chlorine. In case of this accident the amount of chlorine released into the environment is ≈ 200 kg.

Scenario C₄. Loss of integrity of the container shell due to corrosion.

And,

Scenario C₅. Loss of integrity of cut-off valves or locations where it is connected to the container shell.

In case of these accidents, the chlorine leak would occur through an opening with the equivalent diameter 0.3 to 2 mm. A capacity of the emergency chlorine source under the worst option (a liquid chlorine leak) would not exceed (at 20 to 25°C) 400 kg/hr or about 130.0 m³ chlorine/hr (recalculated to gaseous chlorine).

5.3 Risk Assessment

The working group, which performed the risk assessment, used all available information to identify hazards and estimate risks of probable unexpected events. While examining the GUP “Apatityvodokanal” activity, it was noted that there had been no

records regarding accidents and emergencies resulted in chlorine releases to the environment and personnel injury throughout the enterprise operation period. This condition complicated the performance of reliable quantitative estimates of probability of scenarios, which encountered the personnel mistakes. Data provided by the Institute of Safety Engineering for Chemical Industry (Severodonetsk city, USSR) were used to assess emergency risk followed by chlorine release. These data were obtained using probabilistic approach ^{1,2} and the results of statistic processing of information on accidents and equipment failure during fabrication, transportation, storage and application of chlorine both in our country and abroad. Information on accidents and equipment failure were collected and processed by Scientific, Research and Design Institute of Chlorine Industry, Scientific and Production Association "Sintez" and RF Gosgortekhnadzor. It is important to note also that this data were obtained mainly for typical chlorine handling enterprises in the former USSR and Russia to which this facility belongs. Therefore, while assessing the risk, the working group considered typical accident scenarios, the reasons of their occurrence and the possible consequences. The action item priority matrix (probability – consequence severity) was constructed to identify the most critical scenarios and due dates of performing the corrective actions.

Generalized statistic data on the assessment of equipment failure frequency for accident scenarios considered at GUP “Apatityvodokanal” (C₁- C₅) are presented below in the table 3. The table demonstrates that loss of integrity of stop valves (Scenario C₅) presents the most danger in terms of chlorine releases due to high probability of such accident which is $1,0 \cdot 10^{-3}$ per year. However, the chlorine releases are negligible, such as $\approx 0,06$ t, thus the depth of hazardous chemical contamination area is minimal.

Table 3.

Importance of event probability leading to chlorine releases and chlorine release magnitude under emergency and accidents at GUP “Apatityvodokanal”

№	Type of equipment failure	Failure probability (incident), year ⁻¹	Chlorine release magnitude, tonnes
1.	Destruction of cask containing liquid chlorine (Scenario C ₁)	$1.0 \cdot 10^{-5}$	Up to 1

¹ A.J.Hanly, H.Kumamoto. Reliability of engineering systems and risk assessment. M.: Mashinostroenie», 1984, 528 p.

² E.S.Venttsel. Probability theory. M.: «Nauka», 1964.

2.	Break-away of cask valve containing liquid chlorine (Scenario C ₂)	$0.6 \cdot 10^{-4}$	Up to 1
3.	Break-away of cask valve containing gaseous chlorine (Scenario C ₃)	$0.6 \cdot 10^{-4}$	0.2
4.	Loss of integrity of cask body or pipeline caused by corrosion (Scenario C ₄)	$1.0 \cdot 10^{-4}$	0.06
5.	Partial loss of integrity of cask stop valves (Scenario C ₅)	$1.0 \cdot 10^{-3}$	0.06

Assessment of possible damage

Assessment of damage to the environment in case of accident resulted in destruction of tank containing liquid chlorine was conducted in accordance with methodological recommendations of Lenniigiprochim³.

The assessment has demonstrated that corresponding damage to the environment (in the prices for the end of 2001 for energy carrier and water supply) reaches 50 thousand rubles.

Damage caused by destruction of storage equipment – cask containing liquid chlorine – is estimated as 40 thousand rubles in the prices for the beginning of 2002.

In case of accidents under Scenarios C₁ through C₅ the damage to the individuals will depend upon the number of injured, cost of their treatment, compensation to affected families and cost of new personnel training.

Assessment of possible number of injured

Assessment of the number of injured and their severity differentiation was conducted in accordance with methodologies for forecasting and assessment of chemical situation during accidents which were developed and recommended by scientific and research institute VNII GOCS MCS of the Russian Federation.

Possible number of injured was assessed with regard to a number of individuals covered by chlorine hazardous contamination area. The size of this area was identified in

accordance with SN&P documents such as 2.01.51-90 “SO engineering measures”, PB 09-322-99 “Safety rules for chlorine manufacture, storage, transportation and application” and other documents recommended by regulatory bodies.

Recommendations and data to identify the category of accident consequence severity for personnel and population were graciously provided by Dr. Thomas I. McSweeney (Battelle, USA) (see Table 4).

Table 4.

Categories of accident consequence severity

Categories of impact to health under analysis of process hazard				
On site		Reasonably anticipated impact to health	Off site	
Category	Qualitative description		Category	Qualitative description
6+	Extremely high	Numerous fatalities or numerous evidences of chronic diseases	7+	Catastrophic
5	Very high	Fatalities or evidences of chronic diseases	6	Extremely high
4	High	Immediate decline in health or chronic diseases	5	Very high
3	Medium	Injured with long period of disability or serious impact to health, hospitalization is required	4	High
2	Low	Medical treatment	3	Medium
1	Very low	Negligible impact to health	2	Low

The data received with regard to the injured differentiation and category of consequence severity of potentially possible accidents at GUP “Apatityvodokanal” are presented below for different scenarios under consideration (see Table 5).

³Methodological guidelines on assessment of chemical facility impact to the environment. L.: «Lenniigiprochim», 1987.

Table 5.

Differentiation the injured and categories of accident consequence severity at GUP “Apatityvodokanal”

№№ of accident scenarios	Fatalities, pers.	Heavy and medium injury, pers.	Minor injury, pers.	Threshold	Total number of injured, pers.	Category of accident consequence severity
C ₁	2	3	4	11	20	5
C ₂	1	1	2	6	10	5
C ₃	0	0	0	2	2	1
C ₄ , C ₅	0	0	0	1	1	1

Action priority matrix (probability – consequence severity) provided by the U.S. side was used to make a decision on the necessity to reduce the risk (see Figure 5).

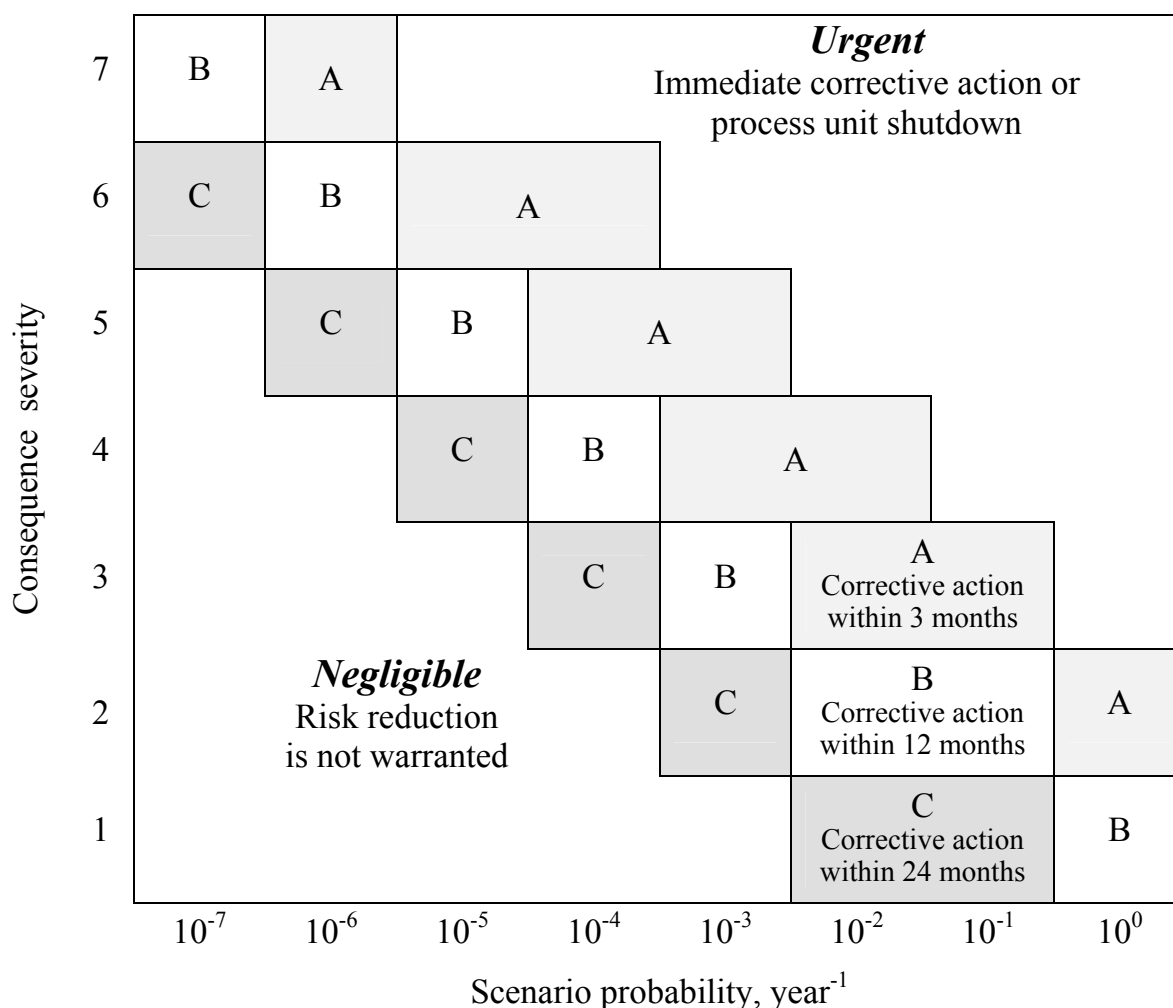


Figure 5. Example action item priority matrix.

Different areas of the matrix demonstrate the necessity, priority and due dates of performing the corrective actions. The action item priority matrix obtained on the basis of the examined scenarios of potential accidents (C₁-C₅) at GUP “Apatityvodokanal” is presented in Figure 5,a.

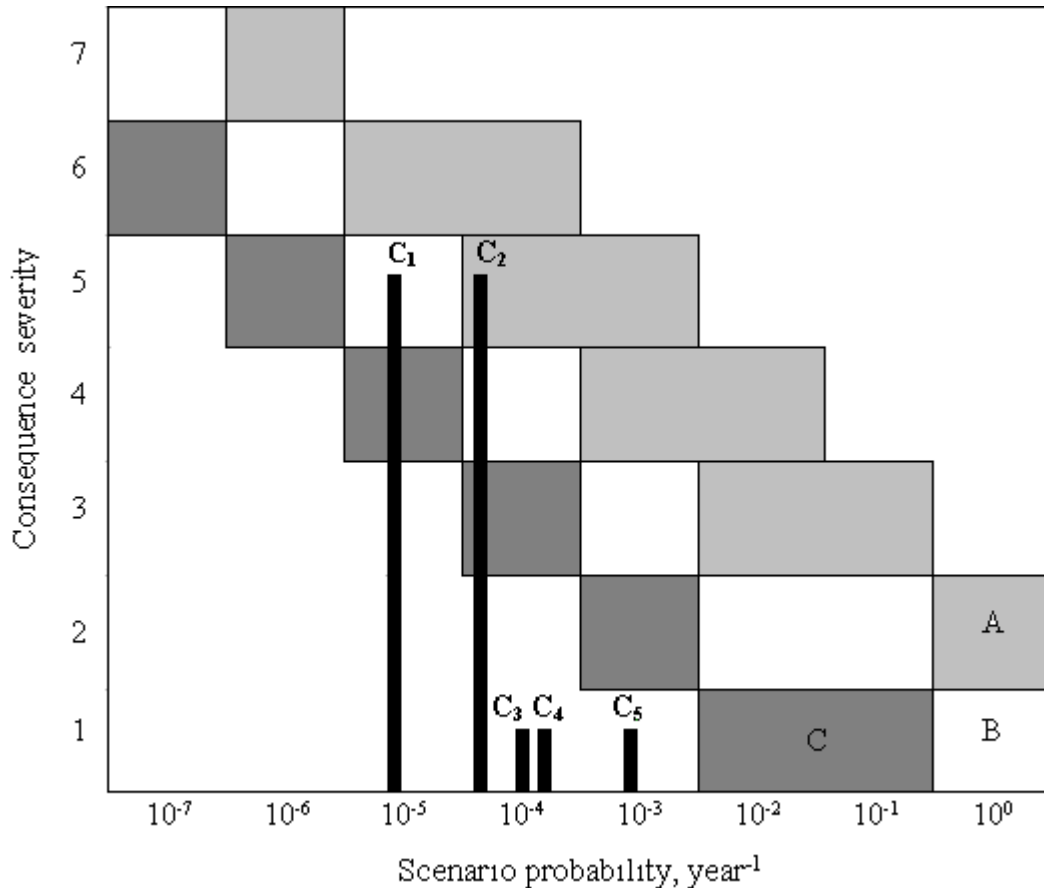


Figure 5,a. Action priority item matrix for GUP “Apatityvodokanal”.

Analysis of the data obtained in this section allows to make a conclusion that accidents under scenarios C₁ and C₂ are the most hazardous in terms of consequences.

Corrective actions within 12 months or within 3 months are required for scenario C₁ and C₂ correspondingly in accordance with probability–consequence severity matrix to reduce accident risk.

Accident risk under scenarios C₃ through C₅ can be considered as acceptable.

Scenario C₁ may become a reality at GUP “Apatityvodokanal” under the following conditions:

- Drop of the cask containing liquid chlorine during loading-unloading operations due to the fact that freight (cask) lifting devices and crane jibbing

are not equipped with two independent brakes (requirement of PB rules 09-322-99, para.8.b);

- When cask transportation vehicle spilled into the ditch (as a result of inattention or professional impropriety of the driver to be detected during corresponding testing procedures which are not presently implemented at the plant) followed by cask drop due to the lack of cask rigid fixture in the cells of vehicle carriage body;
- Cask overflow at chlorine supplying plant as well as due to the lack of entry weight control of the casks containing liquid chlorine to be stored at the warehouse.

Emergency situation under scenario C₂ may occur in case of cask drop during loading-unloading operations and transportation due to the reasons indicated above for scenario C₁.

Cask valve break-away under scenario C₂ may occur also due to corrosion caused by ejector water ingress to chlorine pipes and casks. This is due to the fact that LONII-100K chlorinators don't provide reliable performance of check valve of chlorinator ejector. Lack of continuous automated control over cask dump process contributes to the situation.

The scenarios C₁-C₅ in Figure 5,a are unable to demonstrate clearly all details of specific actions needed to reduce the risk down to an acceptable level. The identification of consolidated scenarios is mainly due to the lack of any data on emergencies, deviations of technological parameters or operator errors throughout the enterprise operation period. Probabilistic characteristics of the concerned scenarios were obtained on base of an analysis of the operating experience of similar-type equipment at similar-type facilities in the former USSR and in Russia during 30 years. This was the deciding factor in favor of choosing consolidated scenarios.

Thus, when elaborating specific recommendations aimed at reducing the risk, the experts were principally guided by requirements of national standard & regulatory documents.

In the next project it will be necessary to pay greater attention to examine written operational procedures and training and development of the scenarios maintained to specifically focus on human factors as a risk factor.

5.4 Alternatives to risk reduce

GUP "Apatityvodokanal" conducted investigations and discussed with municipal officials the possibility to use deep-water wells to provide the city with water and reduce chlorine quantities used in water treatment system. According to preliminary assessments carried out by the enterprise the cost of project implementation will approximately amount to 130 mln rubles. Risk reduction measure was not investigated in details in this work due to the lack of funds in municipal budget. It should be noted that this project will meet only 70% of municipal water demand. It seems difficult to eliminate or considerably reduce chlorine quantities used for water decontamination even in case of the above project implementation taking into account degradation and length of Apatity water piping systems.

6 RISK REDUCTION RECOMMENDATIONS

The results of the investigation lead to the conclusion that reconstruction of some process areas is required to ensure reliable and safe operation of chlorination plant in accordance with the requirements of regulatory requirement. This should be a planned activity based on comprehensive risk management program which is to demonstrate measures to implement recommendations of the working group established at GUP “Apatityvodokanal” presented below. Implementation of such a risk management plan may be in accordance with ISO 14001.

The program should include the following:

6.1. Develop and implement system designs for emergency chlorine release absorption in sanitary columns at chlorine processing facilities.

6.2. To provide reliable monitoring and control over chlorine flow conveyed for water decontamination and prevention of water ingress to chlorine pipelines of water chlorination process flow charts, it is required to replace LONII-100K chlorinators by vacuum ones. This will ensure reliable automatic cut-off of chlorine supply if feed water is not supplied to ejector (that is when vacuum pipeline pressure is increased up to atmospheric); for example, chlorinators of “Advantse” type («Wedeco KFT» (Hungary), of Esco Engineering Corporation etc. certified by Gosgortekhnadzor of Russia for application on the territory of Russia (Information letter of Gosgortekhnadzor of Russia, reference number № 11-11/67 dated by 03.03.97).

6.3. Develop a road-map and time line for gradual replacement of valves installed at chlorine pipelines by those recommended by Gosgortekhnadzor of Russia.

6.4. To implement continuous remote control of chlorine weight in the cask (cylinder) during Cl₂ take-off, it is required to replace mechanical scales by strain-gauge ones developed by TOO “Tenzoizmeritel” (113191, Moscow, Kholodilny per. 1, tel. (095) 955-27-47, 955-48-43) and certified by Gosgortekhnadzor of Russia for application at chlorine facilities.

6.5. Equip personnel of chlorination plant with protective suits intended to protect against 100% gaseous chlorine and local exposure to liquid chlorine for prompt accident localization.

6.6. It is necessary to install wheel guards at the storage facility to prevent vehicles from crossing the limiting line and run over the casks placed for storage.

6.7. Equip cask transportation vehicles with special devices to provide secure stowage of the casks in the vehicle carriage body and their fixed position during transport.

6.8. Implement psychological testing of personnel involved in operation of chlorination plant, chlorine transportation etc. for professional propriety according to the methodologies approved by Gosgortekhnadzor of Russia.

Implementation of measures planned by Process Control Commission (the list is presented in section 4) and recommendations of risk assessment group developed in the framework of this pilot project will enable the enterprise to reduce the risk of accidents with the most severe consequences to acceptable levels. Additionally it will improve operational safety of the industrial facility in question and its emergency resistance level in accordance with industrial safety requirements contained in the relevant regulatory documents being in force in Russia.

Attachment 1. ISO 14001 Documentation of Meetings 18-22 September 2000

Apatity Water Utility Pilot Project

The project team assembled in Murmansk on the morning of 18 September at the regional offices of EMERCOM.

From the U.S.

Leonard Johnson, UAF,
Tom McSweeney, Battelle,
Bruce Russell, JS&A, project leader

Translator

Vladimir Patrushev

From Finland,

Seppo Lehto, Lapland Regional Fire and Rescue Service,

From EMERCOM, Russia

Boris Goldfarb, Head of Emergency Prevention and Response Department,
Moscow

Yuri Panchenko, Chief expert International Affairs, Moscow

Valeri Lishik, Head of Main Directorate, Murmansk Region

Leonid Bagichev, Head of Radiation and Chemical Protection Department,
Murmansk

Natalia Duposkaya, assist to Mr. Lishik

Vladimir Bepalov Head of Emercom Main Directorate, Apatity (joined project team in Apatity later)

From IBRAE, Nuclear Safety Institute

Alexander Shickin, leading scientific researcher (risk assessment)

From the State Mining and Industrial Safety Agency (Gosgortekhnadzor)

Nicole Sverdlenko

From Russian Chlorine Safety Center

Alexander Steblev, chief expert

We reviewed and agreed upon project goals and reviewed the selection of the project facility. Of course, these would have to be reviewed, modified as appropriate and accepted by the project facility.

Project goals: The hazardous material identified for the risk assessment and source control is chlorine. Chlorine is widely used in Russia for drinking, wastewater sanitation, and industrial purposes, including nuclear research, in a wide range of applications. The success of the pilot should lead to similar projects, in particular source control projects at industrial facilities handling and or storing radioactive materials.

The range of source control or emergency prevention measures may include, but is not limited to: reductions in the amount of materials used; safe handling, operating and storage practices; alternative materials; the reliability of protective devices; equipment maintenance; personnel training programs; equipment upgrades (best available prevention technology); and management of external hazards.

The project draws upon U.S. and Russian government officials and experts in hazardous materials handling, risk assessment (drawing expertise from the Russian nuclear industry) and technical expertise of other EPPR working group member countries. The risk assessment approach that will be employed, while commonly practiced in the west was new to the Russians. The project will rely on an international standards-based approach for the safe handling, storage and transport of a specific hazardous material, and will follow the ISO 14001 Environmental Management Systems Standard. ISO 14001 is designed to enable an industrial facility to among other things

- establish a structure and programs to implement the environmental policy and programs, and achieve objectives and targets,
- facilitate planning, control, monitoring, identification and implementation of corrective actions, auditing and review activities to ensure both that the policy is complied with and that the EMS remains appropriate; and

- be capable of addressing unique conditions such as the Arctic, and adapting to changing circumstances.

Project facility: The chemically hazardous facility in Murmansk Region using chlorine to participate in the project be the State For-Profit Firm *Apatitvodokanal* [Apatit water utility - *trans*]. The general manager is Vitaliy Norov. Valention Kolobov is chief engineer of Apatity water utility. The main purpose of the plant is to supply drinking water to the population and economic facilities of the towns of Apatity and Kirovsk and the village of Umba, and to process wastewater. Chlorine reserves there are 39 tons.

After being introduced to the management of the Apatity water utility, briefed the deputy mayor of Apatity. The project team was then provided a detailed briefing by the general manager and chief engineer of the Apatity Water Utility. They provided a technical overview of the facility, plant operations, distribution system, tariffs and rate structure, volume of water and volume of chlorine, Ministry of Health sanitary laws, transportation and supply problems. The chief engineer of both the Apatity and Murmansk water utilities described their "dreams" or objectives for new equipment to update their facilities. New equipment included computerized chlorine injection and monitoring devices (thus reducing the volume of chlorine used) and state of the art chlorine scrubbing equipment in the event of an accidental release. The general manager of Apatity water works described his "dreams" or objectives. He would like to sink a well(s) to tap pure water to replace the lake water he now draws from which requires heavy treatment in the spring and fall and smells of ferrous sulfide. Thus reducing the volume of chlorine used.

The project team toured the main chemical treatment and storage plant, and laboratory, and met the plant workers and lab personnel. Chlorinating of water is a simple process. None of the process is computerized. Rooms make no pretense of being airtight. There is only one chlorine monitor in each room; both set at knee level. The hoist cranes are regularly inspected by the State Mining and Industrial Safety Agency (Gosgortekhnadzor). The chlorine expert from the Chlorine Safety Center advised that this was a typical facility.

Cold is not a problem (they do need to look at cold and transportation), the storage facility does not go below 5°C. However, they report that 3% of chlorine tanks they receive are overfilled or have faulty valves. The chlorine has impurities that require filtration. The supplier also demands return of the tanks in a short timeframe and thus might lead to pushing too much chlorine through the system. Finally, the chlorine comes in by rail car and they only have 2 hours to unload the rail car. Transportation and supply will be examined in the risk assessment. While the facility is located several kilometers below the town, there is an industrial plant next door with 2000 workers.

On 20 and 21 September, Tom McSweeney initiated discussions of risk assessment and hazards screening. Surprisingly, these were the most difficult discussions. Part of the reasons for the difficulties lay approach proposed by Mr. McSweeney provided for the prioritization of risk, which they were not familiar to the Russian members of the project team before and found not to comport with existing compliance and emergency response regulations. We re-grouped and, with the help of Alexander Shickin, IBRAE presented an alternate approach commonly used in the US and throughout the rest of the world. The project team formed the risk assessment team headed by Alexander Shickin of IBRAE, team (with Mr. McSweeney as oversight and technical advisor as needed) and started work on the risk assessment. The risk assessment team includes:

Apatity water utility, chief engineer

Alexander Shicken, IBRAE

Leonid Bagichev, Head of Radiation and Chemical Protection Department,
Murmansk

Mr. McSweeney as oversight and technical advisor

With the risk assessment initiated, the project team discussed environmental management systems and the specifics of the ISO 14001 standard. EMERCOM and IBRAE had distributed the Russian language version of the ISO 14001 standard. Every Russian participant had read it and was conversant in it. We cross-walked the risk assessment process to the ISO 14001 standard. We noted that there is an ISO 14040

document on risk, life cycle analysis, which is another way of evaluating risk. We discussed the flexibility of the ISO 14001 standard and that that the facility could just focus on chlorine management if it chose and as the pilot project planned. (The facility handles propane and oil products for example, but these do not pose the same risk from and emergency perspective). We then reviewed the second step in developing an ISO 14001 program for this facility, that of the environmental policy statement. We reviewed a sample a sample environmental policy statement. As an essential element of a successful facility, EMS is top management commitment with clear goals and objectives. The project team was impressed by the commitment to excellence by the general manager and his chief engineer, and noted that both the general manager and the chief engineer had articulated their commitment and objectives over the two days of discussions and that putting this to paper in a concise manner would be straight forward task. Alexander Shickin, IBRAE will assist.

Before closing these discussions we reviewed the requirements of the environmental management system and noted that the project team had already begun most of the processes: for example, legal requirements, environmental aspects (risk assessment), objectives and targets, programs (continual improvement, phased in over time with management review), training, communication (both internal and external), preparedness and response.

Before leaving Apatity we out-briefed the mayor and were interviewed by the Apatity media on the project and next steps. The general manager offered tours of his facility. The mayor was interested in upgrading the water supply at the waterworks and asked about the safety at the facility, and expressed concern about the rail transport/transfer of chlorine tanks.

Mr. Russell will work with Alexander Shickin to develop a project plan and timeline for the pilot project. (Mr. McSweeney and I will work with Mr. Shickin through me on pollution/emergency prevention approaches the risk assessment team may not look at / be aware of). The below list includes areas that Tom McSweeney suggested that the risk assessment team pay particular attention. Note that Tom McSweeney did not

specifically any elements related to emergency response. They clearly should be part of the analysis as well, and we should look to EMERCOM for guidance.

- Written procedures and training
- Maintenance program on safety related systems
- Chlorine cylinders with protective covers during handling
- Visual checks for degradation of lifting systems
- Cylinder weighing upon receipt (to detect overfilling)
- Chlorine detectors in storage and addition room that alarm locally and remotely to warn of a chlorine release
- Manually actuated spray system in storage room
- Downward flowing ventilation system in storage and addition room
- Valve cover assembly to open stuck open cylinder valves.

There are probably others that would only be observable by spending more time reviewing documents and observing critical or off normal operations. Cylinder receipt and change out would be two examples of critical operations. Recovering from a stuck valve or handling of defective cylinders would be examples of off-normal operations should be physically observed by the risk assessment team. Such observations might uncover additional safety. Such as, do they perform a leak check at the time of receipt - using some type of portable electronic sniffer or chemical detector that we did not see but they might have at their facility. The risk assessment team should uncover transportation and supply problems that go beyond that facility, but affect the facility.

Attachment 2. ISO 14001 Documentation of Working Travel of the Risk Assessment Team on Apatity Water Utility, 11-15 February 2002
Apatity Water Utility Pilot Project

To carry out process hazard analysis and to perform risk assessment, the following team of experts was created:

- A. Shickin – Facilitator from IBRAE RAN (Nuclear Safety Institute of the Russian Academy of Sciences);
- A. Steblev – Chief expert from Russian Chlorine Safety Center;
- V. Norov. – Director of Apatity Water Utility (Apatitovodokanal);
- A. Drozdov – Chief of Apatitovodocanal Production and Technical Department;
- V. Androssik – Engineer on Labor Protection.

Work was performed at Apatity Water Utility during February 11 through 15, 2002 and included:

- Systematization of different information related to the utility (layout, schematic diagram of processes, flow sheets, emergency plan, safety engineering manuals);
- Visual inspection of potentially dangerous units and installations of the utility (railway platform for loading /unloading of containers with chlorine, lorry performing containerization, chlorinating installation and pipelines);
- Cursory examination of the actual practice of the utility operation, checking up for the availability of individual protectants as well as for proper operation of both the accident protection system and the accident localization system.

Using the obtained results, basic scenarios of initiating potential emergency situations at the utility were developed and studied.

Attachment 3. Reviews of content of the final report

“Analysis of Risks of Emergencies to Population and Territory, and Development of Measures to Reduce the Risks as applied to the «Apatityvodokanal» Utility”

EMERCOM of Russia provided the following review and comments.

The reviewed work is devoted to the principle risks exposure and risk assessment at the potentially hazardous industry object – the chlorine consumption store of GUP “Apatityvodokanal”.

Resolving of this problem is very important as it allows to create the prerequisites for developing of administrative plans of providing of secure work conditions whereby the requirements of the ISO 14000 process.

In the reviewed work, the assessment of accidents risk was conducted in accordance with methodology developed in this work and based on methodology provided American partners. Assessment of the number of injured and their consequence severity differentiation was conducted in accordance with methodologies for forecasting and assessment of chemical situation during accidents which were developed and recommended EMERCOM of Russia and Gosgortekhnadzor.

This approach allowed obtaining information sufficient for the practical purposes about the real risks at the considered and similar enterprises.

The risk assessment of the accident risk conducted at the GUP “Apatityvodokanal” allowed to determine and recommend complex of valid measures of risk diminution aimed at the exploitation safety and anti-accident steadiness of the potentially dangerous object.

The obtained results are doubtless of interest for all chlorine producing and consuming enterprises in Russia.

For obtaining of more detailed information concerning hazard and risk assessment at chlorine producing and consuming enterprises in Russia, it is expedient, in addition to the results obtained in this work, to consider the possibility of independent study of such important problem as safety of liquid chlorine transportation as the scale of this operation in Russia for recent years grew 5 times more. Every month more than 100 thousand tons

of liquid chlorine is transported by rail for a distance of 3000 km, more than 2500 tank-wagons with liquid chlorine are on the way or at railway stations. That is potentially dangerous for the population and environment and requires adequate preventive and protective measures for reducing of danger of emergency occurrence at transport.

In whole, the presented work deserves positive assessment.

GUP “Apatityvodokanal” provided the following review and comments.

The presented analysis on the emergency risk at GUP “Apatityvodokanal” issued by IBRAE is valuable not only for the examined object, but for all chlorine producing and consuming enterprises in Russia.

In the work, the analysis of possible emergency situations shows that their consequences can lead to victims while realization of the measures recommended by the authors will allow reducing to acceptable level the possibility of an accident accompanied by chlorine release.

While planning the program of measures to increase safety of the enterprise operation, the recommendations given in this report will be taken into account.

The work is done up to high standard and deserves positive assessment.

Russian Chlorine Safety Centre provided the following review and comments.

The project presented for consideration is devoted to risk analysis of the emergency at GUP “Apatityvodokanal”. From the description of its characteristics, it can be concluded that choosing of the chlorination GUP “Apatityvodokanal” as a model is valid as it is one of the typical water-processing enterprise, widely spread in Russia, built according to the type projects of the series 901-3-14/70 “The chlorinating system with productivity of 5-50 kg per hour, combined with consumption store of the chlorine” and developed by the scientific-research institute of experimental designing in 1970. it is necessary to note that, by the present, the technical design of this series projects is out-

of-date and, as it is fairly noted in the considering project, not suitable for the requirements of the currently in force in Russia normative technical documentation.

The system of production control applied at the enterprise allows timely measure developing based on the analysis of the industrial safety conditions at the object and aimed at anti-emergency steadiness of the object and of the environment damage preventing.

Applying by the developers the action item priority matrix (priority of the separate actions” (probability – weight of consequences) provided American participants while risk analyzing allowed to take well-grounded decisions on the necessity of risk diminution actions while accidents with the most grave consequences and developing of the effective measures and recommendations for this aim realization.

The work presented is urgent, done up to high scientific standard allowing usage of the results, obtained on the basis of developed methodic approaches, for deep and detailed risk analysis at similar enterprises in Russia.