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Consolidated Reply

Query: Pipeline Damage and Chlorine Spillage- Assessment and Handling - Experiences; Advice

Compiled by G. Padmanabhan and Pankaj Kumar S., Resource Persons and Nupur Arora and Ramya Gopalan, Research Associates

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From Swati Mitra, GOI- UNDP' Disaster Risk Management Programme, National Institute of Disaster Management, New Delhi

Posted 24 August 2007

Dear Members,

I work as a Project Associate under the GOI- UNDP' Disaster Risk Management Programme and assist the National Institute of Disaster Management for designing disaster management course modules. Currently I am working on a Module on Water & Sanitation during Emergencies.

One of the issues faced by the target group for this course is on effective handling of Chlorine Spillage or Leakage as huge quantities of chlorine are stored in water treatment plants. By this, I do not mean methods of chlorination we normally have like the Gas chlorinators, Hypochlorinators, Batch Method etc.

Another issue, which often comes up is, damage assessment of the water pipelines after disasters. Should there be a sabotage, which is rather then disrupting the water flow, how could we contain that section and arrest the damage? We do have methods like-

- Monitoring night flows, as then regular water flow is stopped, and this would give an idea to the amount of water lost and repair work can be accordingly done.
- Individual zoning, wherein valves are closed within the zones, to isolate sections of the pipe, and water flow is checked.

- Checking leakages by using acoustic equipments, which detects sound & vibration induced by water as it escapes from pipes, (it is 500-800 hertz when it leaks from the pipe, 20-30 hertz when it touches the soil or surrounding areas).
- Electronic listening sticks are useful for underground pipes etc.

I request members to share their experiences on handling chlorine spillage or leakage and conducting damage assessment of water pipelines after disasters and to suggest innovative, feasible and hands on methods for the same.

Your inputs will help us to improve our programmes to enable enhancing preparedness against such leakages, and will therefore be greatly appreciated.

Responses were received, with thanks, from

1. **Taral Kumar, Akar Impex (P) Ltd., Noida**
2. **M. Mehta, Jal Bhagirathi Fondation, Jodhpur**
3. **Sukanta Kumar Rath, UNDP Jagatsinghpur, Orissa**
4. **Surendra Kumar Yadav, National Institute of Health and Family Welfare, New Delhi**
5. **Ajit Seshadri , Vigyan Vijay Foundation, New Delhi**
6. **Mario Suardi, Water and Sanitation Program-South Asia, New Delhi**
7. **V. Kurian Baby, Civil Lines, Thrissur**
8. **Amit Tuteja, SEEDS, New Delhi**

Further contributions are welcome!

Summary of Responses

Responding to a query on managing pipeline damage and chlorine spillage, the members focused sharing suggestions for detecting leaks following disasters and designing responses to chlorine spillages in water treatment facilities.

Discussing the **technologies for assessing damage** to water pipelines following disasters, respondents stressed that early detection and repair of breaks and leaks was of utmost importance, because if there were subsequent disasters, the damage would be manifold.

Using acoustic vibrations for detecting breakages is not a reliable approach, felt members, because they cannot accurately detect leaks in underground pipes. Instead, they suggested zoning of pipelines with isolation valves, but if there are no drawings indicating the pipe routes, this approach could be problematic. Another effective technique mentioned was using sensors connected to flow meters, which enables calculation of any variation (possible leakages) in the flow amount from the start to downstream locations. Similarly, respondents suggested energizing the pipe network and using hydraulic pressure drops in sections to detect leakages and shared a recent paper on a method for detecting changes in point impedance using high frequency excitation to detect leakages.

Additionally, the group stressed that detection of such leakages and breakages needs to be based on preventive and breakdown principles and schedules and need to lead to predictive routines rather than responding to emergency breakdowns. They illustrated this point by mentioning a situation in **Kerala** where a slow response resulted in major contamination of the drinking water supply.

Participants discussed safe **handling of chlorine spillages and leakages** emphasizing that since large quantities of chlorine are stored in water treatment plants, the possibility of leakages always exist. Thus, they stressed taking the utmost care when handling chlorine, since exposure adversely affects the respiratory system, corrodes the skin, damages eyes and can be fatal.

Respondents outlined various **precautions when using** chlorine. They advised that the evaporation area have a switch to allow operators to change from one cylinder to another to feed into the chlorination system, so the empty cylinder could be detached at leisure and sent to the storage area. In the control room, good ventilation, along with doors and windows that shut automatically when sensors detect leakage of chlorine are necessary. A suction system to extract the leaked gas to a sodium or similar scrubber also needs to be in place in the control room. Members also recommended having a means to submerge the leaking cylinder into a water tank and flooding the control area to flush out spilled chlorine needs in the handling area.

Discussing in detail on the proper storage of chlorine, members explained it must be stored in cool, dry, well-ventilated places, and away from heat and sunlight, because it emits toxic fumes at high temperatures. The steel bottles and high-pressure cans containing chlorine need to be in water baths to minimize the impact of potential leaks. Additionally, acids and chemicals must not be stored near chlorine stores, due to a risk of fire. Respondents advised conducting regular visual and X-rays examinations of the cylinder and safety valves to guard against potentially leaking cylinders.

The floor of the storage shed needs to be smooth, with no sudden drops, to enable easy transport of cylinders. The group suggested arranging containers so they can utilized on a “first-come, first-used” basis, since long storage of chlorine leads to hardening and leakages in valve packing. Moreover, only 80% of the cylinder needs filling, to allow the liquid chlorine to expand. Members also cautioned that chlorine cylinders are necessary for storage vessels, but not for controlling the flow, which could be dangerous.

Additionally, protective gear and equipment for the staff handling chlorine is necessary, members advised using Polyethylene, fiberglass reinforced epoxy and rubber lined equipment to handle chlorine. They also recommended regular testing of chlorine sensors, alarm systems, water hydrants and emergency kits (gaskets, claps, spanners, screws, chains, pins, etc.) to ensure preparedness against any emergency. This type of preparedness worked well in **Orissa** when tankers containing chlorine gas began leaking in a densely populated urban area. The thickness of the pipeline, the flanges and joints must also be regularly checked respondents pointed out. Discussants also outlined various **mitigation steps to take** during a chlorine leak:

- Close all valves and packing of chlorine containers
- Move everyone to a higher elevation or perpendicular to wind direction, since chlorine is heavier than air and tends to accumulate near the ground
- Only allow trained personnel to attend to the leak, equipped with suitable protective equipment
- Make Ammonia torches easily available to facilitate easy detection of leakages

Along with mitigation, members delineated several **elements a preparedness system requires**:

- Operation and Maintenance manuals to contain detailed instructions for handling chlorine equipment and mitigation measures during a leak
- Response system designed by experienced individuals and include mock drills to enhance preparedness
- Periodic appraisal and feedback on response system to enhance quality of data and prepare

- Capacity building of personnel handling chlorine at various stages (storage, handling and mitigation) to protect against accidents and training in how to providing first aid
- Organization of alternative water sources to use in case of chlorine contamination
- Moving to alternate filtration technologies such as Silver Ionization

Finally, discussants underlined the importance of awareness, capacities and systems to prepare for both pipeline damage and chlorine spillage based disasters, arguing only a long-term approach, would institutionalize preparedness systems against disasters.

Comparative Experiences

Orissa

Handling Chlorine Leakage, Jagarsinghpur *(from Sukanta Kumar Rath, UNDP Jagatsinghpur, Orissa)*
In Paradeep Municipality of Jagatsinghpur there are eight Major Accident Hazard (MAH) units handling ammonia, chlorine, sulphur etc. Four tankers containing chlorine gas started leaking one day. Then the local industrial safety units of Paradeep Phashates Ltd and Indian Farmers Fertiliser Co-operative Limited helped the Central Industrial Security Force (CISF) personnel to diffused the chlorine gas leakage using their technical know how by digging the required dimension of earth and using lime to contain the leak.

Kerela

Phenol Spillage Leading to Water Contamination, Thissur *(from V. Kurian Baby, Civil Lines, Thrissur)*
A massive phenol spillage occurred two kms upstream from the Peechi reservoir, the mainstay of drinking water supply to the entire Thrissur Corporation. The flow of contaminated water was allowed to reach the reservoir. Then despite mobilizing the entire district machinery and expert agencies like National Environmental Engineering Research Institute to monitor the water quality on a continuous basis, it took more than three months to get the situation stabilized, resulting in high costs.

United States

Multiple Train Car Derailment Involving Hazardous Materials, Florida *(from Ramya Gopalan, Research Associate)*
In 1997 thirty-four railway cars some transporting chlorine, hydrogen peroxide, and sodium hydroxide derailed in a remote area of the state. A team from MEREDITH supported project management efforts with safety, logistical, environmental, and financial services. They also mobilized equipment and personnel to support the clearing of the tracks, off-loading damaged cars, containing the environmental impact, and cleaning-up the contamination. Read more

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Related Resources

Recommended Documentation

Feasibility of Using Impedance-Based Damage Assessment for Pipeline Structures (*from Mario Suardi, Water and Sanitation Program-South Asia, New Delhi)*
Research Article; by Gyuhae Park, Harley H. Cudney and Daniel J. Inman; Center for Intelligent Material Systems and Structures, Virginia Polytechnic Institute and State University; Blacksburg, Virginia, United States; 2001
Available at http://www3.interscience.wiley.com/cgi-bin/abstract/83002260/ABSTRACT?CRETRY=1&SRETRY=0. (PDF Size: 224 KB)

Article discusses ways to utilize capability of impedance method in identifying structural damage in areas needing quick condition monitoring, like in post-earthquake analysis of a pipeline system.

Safe Handling of Oil and Chemicals *(from Nupur Arora, Research Associate)*
Report; Alaska Department of Environmental Conservation; Alaska, USA
Available at http://www.dec.state.ak.us/spar/docs/SafeHandlingBrochure3.pdf (PDF Size: 2.09 MB)
Explains how through effective prevention, preparedness and response the Spill Prevention and Response Division of Alaska Department of Environment Conservation manages oil spills

From Ramya Gopalan, Research Associate

Chemical Spillage - A Preventable Disaster?
Paper; by L. Rosenberg and U. Shabshin; Ben Gurion University of the Negev; Annual Medit. Burns Club Vol. 8 No. 3; Israel; September 1995
Available at http://www.medbc.com/annals/review/vol_8/num_3/text/vol8n3p169.htm
Considers accidents caused by spillage of dangerous chemicals and their possible prevention, citing experience in Israel and of findings of researchers across the world

Addressing Gaps in Environmental Emergency Planning: Hazardous Materials Releases During Earthquakes
Article; by Michael K. Lindell and Ronald W. Perry; Journal of Environmental Planning and Management, Vol. 39, Issue 4; December 1996; Permission Required: Yes. Paid Publication
Abstract Available at http://www.informaworld.com/smpp/content~content=a713676393~db=all
Highlights that earthquake-induced hazardous materials released when transported by rail, truck or pipeline receive little research & management attention; provides suggestions to address this

Hazard Identification and Risk Assessment
Report; by N. C. Nigam, A. K. Maheshwari and N. P. Rao; Indian Farmers Fertilizer Co-operative Limited (IFFCO)
Available at Link (PDF Size: 189 KB)
Brief on hazards and risks of exposure to chemicals (e.g. chlorine, ammonia) due to accidents; break down of equipment, storage tanks or pipeline failures, outlining need for risk analysis

Recommended Organizations and Programmes

From Sukanta Kumar Rath, UNDP Jagatsinghpur, Orissa

Indian Farmers Fertilizer Co-operative Limited (IFFCO), Orissa
IFFCO, Paradeep Unit, Village Musadia, P.O. Paradeep, District Jagatsinghpur, Orissa 754142; Tel: 06722 223345/2835/2961/2883; Fax: 06722-222857; http://www.iffco.nic.in/applications/iffcowebr5.nsf/?Open
Leading farmers cooperative which acquired the fertilizer unit of Oswals at Paradeep, involved in helping to diffuse chlorine gas spillage at Major Accident Hazard (MAH) units.

National Environmental Engineering Research Institute (NEERI), Kerala *(from V. Kurian Baby, Civil Lines, Thrissur)*
Nehru Marg, Nagpur, 44002; Tel: 091-0712-2249885-88/970-72; Fax: 0712-2249900;; http://www.neeri.res.in
Supports industries in solving problems of environmental pollution/monitors water quality, involved in phenol spillage in Thissur clean up efforts dealing with contaminated water in pipes.

Recommended Portals and Information Bases

Doulton Drinking Water Filters Website, Doulton and H2O International Inc., Canada *(from M. Mehta, Jal Bhagirathi Foundation, Jodhpur)*
http://www.doulton.ca/silver.html#chlorine

Website contains research articles on Silver Ionization Technology, which is increasingly being used for filtration in public water supply

Incidents, The Meredith Management Group Inc., Paoli *(from Ramya Gopalan, Research Associate)*
http://www.mmg-ems.com/services/experience/incidents.htm; Tel: 610-725-8286; info@mmg-ems.com

Provides examples of emergency management and risk mitigation services provided by Meredith team in events of pipeline/vessel damage causing spillage of chlorine, oil, etc.

Responses in Full

Taral Kumar, Akar Impex (P) Ltd., Noida

I assume you mean spillage or leakage of Chlorine while it is stored in large quantities in water treatment plants. While other members will respond to that, I wish to give inputs regarding damage assessment of water pipelines. We have ourselves tried our hand with the acoustic means that detect sound and vibrations. Unfortunately, even experts detected leakages where there were none, but where there were illegal connections. The other problem we encountered with Delhi Jal Board was that they never had open water pipes. They only kept pipes buried in the ground, which interfered with the ultrasonic vibrations.

Zoning of the pipelines with isolation valves is a much better idea in the Indian context. However, we found absence of drawings, which indicated water pipe routes. In one instance, we actually had to get hold of a retired fitter who told us where the pipe had been buried. We even had difficulty in locating the same since the whole area had changed in 35 years. What was once an open ground had been converted to the area near Moolchand Crossing, making things even more difficult.

However, a very effective method is to locate sensors at strategic places that can be connected to a portable water flow meter that tells us reduction in water flow downstream. This way, we know how much water started from point A and is being consumed along various points downstream. Any subsequent variation may be categorised as illegal connection or a leakage.

Hope to learn and share more information with you.

M. Mehta, Jal Bhagirathi Foundation, Jodhpur

I just wanted to share with members that increasingly, instead of chlorination a new technology that is increasingly being used for filtration in public water supply is that of Silver Ionization (See http://www.doulton.ca/silver.html#chlorine).

Sukanta Kumar Rath, UNDP Jagatsinghpur, Orissa

Let me share a brief case study on handling Chlorine leakage at Paradeep, Jagatsinghpur. For your information there are 8 Major Accident Hazard (MAH) units in Paradeep Municipality handling Ammonia, Chlorine, Sulphur etc., also there is Paradeep Port Trust. 4 Tankers containing Chlorine gas were purchased from Jayashree Chemicals long back which were lying abandoned by the water treatment authority which was supplying piped water to the township. These tankers were lying in a densely crowded slum area. One day at around 12-Noon, it started leaking. People in panic reported the same to the local administration.

The Additional District Magistrate, Paradeep immediately swung into action. He called local unit of the Central Industrial Security Force (CISF), but found that they are neither having the required technical knowledge of handling the chlorine leakage nor have the equipments to diffuse the same. Then the local industrial safety units of Paradeep Phashates Ltd and Indian Farmers Fertiliser Co-operative Limited (IFFCO) who are handling chlorine gas were called to diffuse the same. The CISF personnel were kept under incident command of the IFFCO safety officer. Under his command the chlorine gas was diffused using their technical know how by digging required dimension of earth and using lime etc. I am waiting the detailed technical report from the Assistant Director, Factory & Boilers, Cuttack, if you require the same; it will be shared with you.

Surendra Kumar Yadav, National Institute of Health and Family Welfare, New Delhi

I feel that as part of the preparedness for Chlorine related disasters, suitable arrangements for managing Chlorine tanks & supplies at sites need to be done, so as to be ready for cases of accidental leakage. The managing personnel must be trained to handle the risky/ accidental situations and such training could be made compulsory for such personnel, so that not only chlorine but also other gases or liquid leakage may be controlled as and when the situation arises.

Ajit Seshadri , Vigyan Vijay Foundation, New Delhi

The queries raised are very intricate and involves plant management principles and practices.

I cite below some prevalent inferences gained on plant management in utilities and services on the subjects given below:

- **Effective handling of Chlorine Spillage or Leakage**
  In most occasions, chlorine is stored in steel bottles or high-pressure cans, all these are to be duly marked and Environmental Protection Agency guidelines to be observed. For safety, these vessels may be contained in water baths, as this would minimize the impacts. Regular monitoring and surveillance practices are to be followed and maintained on a logbook/ sheet.
- **Damage assessment of the water pipelines after disasters**.
  Here again preventive and breakdown maintenance principles and practices are observed. A new concept in preventive schedules has emerged in the last decade and it is called predictive routines. These are to be followed as human populations may be affected at all these sites. Therefore, nothing is left to chance.

Disasters such as earth tremors some times comes in short repetitive bursts, which tends to cause more damage if the initial flaws and breaks in pipelines are not corrected in time and before the reoccurrence of next shocks.

Operation and maintenance:

- E & M of all elements where the medium (such as Chlorine) flows needs to be assessed and attended to.
- Due training need to be given to personnel of all levels with assigning of accountability and responsibility ensured.
- O&M manual to be updated and be currently relevant to all elements in the plant.
- Periodical appraisal and participatory feed back needs to be taken and all data needs to be maintained systematically. Simulated mock-drills need to be organized periodically and the older and more experienced hands could be asked to participate in giving inputs to the training and in developing the training modules.

We welcome and seek more experiences to enrich our knowledge on the issues raised by Swati, which would go a long way to avert disasters and prevent loss of lives.

Mario Suardi, Water and Sanitation Program-South Asia, New Delhi

In my experience, there are two instances when a chlorine spillage or leakage could happen:

a) While handling the chlorine cylinders
b) While replacing an empty chlorine cylinder with a full one

The first thing to do to prevent disasters is to avoid risky situations and risky actions. To avoid risky situations it is required that appropriate facilities are available for handling chlorine cylinders. This means having an appropriate building, separated at least in three areas.

The first one would be the storage area, where the trucks carrying the cylinders can come, unload the full cylinders and load the empty ones.

The second one would be the evaporation area where the active cylinders are located on top of a bascule that allows the operator to monitor whether the cylinder is still active or already empty. Ideally, there should be a switch that allows the operator to change from one cylinder to another already connected to the chlorination system. Then the operator can disconnect the empty one with no hurry, as the chlorination process does not depend on his ability to disconnect the empty cylinder and connect a full one.

The third area is the control room where the operator can check the chlorine dose and the weight of the active cylinder.

The whole building should have good ventilation provided by doors and windows that would shut automatically when the gas detectors sense leakage of chlorine or when the operator activates them. There should also be a suction system that will bring the contaminated air to a scrubber which is a chamber filled up with plastic media with a high specific area to provide good contact area for chlorine to combine with sodium being poured automatically into the chamber in the form of caustic soda or another sodium rich solution.

Protective equipment should be provided to the operators and special care should be taken during the unloading of full cylinders from the trucks.

In many cases this ideal conditions cannot be met but at least, means should be provided for the operator to be able to submerge the cylinder in water.
This could be done by ensuring that the proceedings of replacing the active cylinder takes place in an area that could be easily flooded if a leakage occurs.

The spillage of hypochlorite solution is usually dealt with lots of water for further dilution and discharge into the sewers of the treatment plant.

Storage of chlorine tanks should be done in a covered place where the cylinders are protected from the sun. Regular checks of the cylinders and especially the safety valve should be done visually every time the cylinder is received and with x-ray from time to time according to the National standards.

I am not an expert in the field of assessing damage to pipelines after disasters, but I think that a procedure that could be followed is to energise the network in a phased manner, closing all hydraulic section valves and opening them one by one, monitoring pressure levels and visible leakages. However, I recommend the following document, available only to members of Wiley Eastern:

Research Article on “Feasibility of using impedance-based damage assessment for pipeline structures” by Gyuhae Park, Harley H. Cudney, and Daniel J. Inman. Center for Intelligent Material Systems and Structures, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0261, U.S.A. Available on subscription at
http://www3.interscience.wiley.com/cgi-bin/abstract/83002260/ABSTRACT?CRETRY=1&SRETRY=0.

Abstract
“This paper presents the feasibility of using an impedance-based health monitoring technique in monitoring a critical civil facility. The objective of this research is to utilize the capability of the impedance method in identifying structural damage in those areas where a very quick condition monitoring is urgently needed, such as in a post-earthquake analysis of a pipeline system. The basic principle behind this technique is to utilize high-frequency structural excitation (typically greater than 30 kHz) through surface-bonded piezoelectric sensors/actuators to detect changes in structural point impedance due to the presence of damage. Real-time damage detection in pipes connected by bolted joints was investigated, and the capability of the impedance method in tracking and monitoring the integrity of the typical civil facility has been demonstrated. Data collected from the tests illustrates the capability of this technology to detect imminent damage under normal operating conditions and immediately after a natural disaster.” Copyright © 2001 John Wiley & Sons, Ltd.

I hope this is useful.

V. Kurian Baby, Civil Lines, Thrissur

Two key contextual issues that warrant attention are (i) design dynamic offsite /onsite emergency plans especially for off take /treatment locations during planning and implementation of large the water supply projects catering to major cities and urban agglomerations; (ii) plans for alternate sources that can meet the emergency needs. We had a massive phenol spillage that occurred two kilometers upstream the Peechi reservoir in Kerala that was the mainstay of drinking water supply to the entire Thrissur Corporation. First, we have failed to contain the flow of contaminated water reaching the reservoir; second, despite the entire district machinery mobilized and expert agencies like National Environmental Engineering Research Institute (NEERI) brought in for monitoring water quality on a continuous basis, it took more than 3 months to get the situation stabilized, at very high cost. Many of the drinking water sources adjoining the major highways are susceptible to such disasters.

The challenge here is the extent of knowledge and awareness and capabilities of the people who handle at the cutting edge.

Amit Tuteja, SEEDS, New Delhi

It is widely known and generally accepted that there are many inherent hazards in the storage, handling and use of chlorine. Whenever chlorine is handled, a potential risk is always involved and a serious emergency may suddenly crop up. To avoid that, a high degree of safety and adequacy is required in each & every activity. Please find below few handy tips, pertaining to chlorine handling, to avoid leakage and spillage:-

- As chlorine is soluble into water, water should never be used during the chlorine leak. This is because chlorine reacts with water and forms hydrochloric acid, which is highly corrosive.
- Chlorine containers/ cylinders should be stored only in a cool, dry well ventilated and covered place, and kept away from heat, as it emits highly toxic fumes when heated.
- As Chlorine is 2.5 times heavier than air, it tends to accumulate near the ground. Hence at the time of chlorine leak, it’s advisable to move all the persons to higher elevation/areas opposite or perpendicular to wind direction.

- To attend the chlorine leak, only trained persons should be allowed to attend leak, with suitable mask and respiratory protective equipments. Eye protection is imperative due to chlorine's irritating nature.
- Ammonia torches should be available at nearby places, in order to facilitate the easy detection of any leakage, where chlorine containers are received, stored or used in process.
- The chlorine containers should be arranged in such a way that these can be taken to process on first come first serve basis. This is advisable, in order to avoid the same container remaining in storage for longer periods, leading to hardening to valve packing and possible leakages.
- Chlorine containers should never be stored together with acids/ chemicals, which can cause fire.
- Chlorine pipeline's thickness needs to be checked once in every 6 months, and if it is below the standard limits, then the same needs to be replaced as soon as possible. Also the flange joints and valves need to be checked with Ammonia torch.
- As a matter of safety, the chlorine sensors, alarm system, water hydrants and emergency kits need to be kept ready in working order. Emergency kits consist of gaskets, claps, spanners, screws, chains, pins, etc.
- To stop Chlorine leak, close all chlorine container valves by turning in a clockwise direction. Leaks around valve stem may be stopped by tightening packing nuts in the same clockwise direction.
- While handling Chlorine, PVC & Polypropylene are unsuitable for dry and wet chlorine service. Polyethylene and fibreglass reinforced epoxy give suitable service up to 75 degree Celsius. At normal temperature & pressure, rubber lined equipments are also advised.
- During the filling of Chlorine tonnes, approximately 20% space needs to be kept empty for adequate expansion of liquid chlorine.
- Appropriate training needs to be provided to road tanker driver. He should have a valid licence & certificate of fitness. Apart from this, he should be aware of properties of Chlorine through the MSDS (Material Safety Data Sheet) and should also be capable of administering first aid during an emergency.
- Chlorine container should be used only as a storage vessel, not as a pressure vessel or for controlling the flow. The container should not be given heat treatment.
- In the factory, generally the chlorine tonners are moved by rolling. Hence at this place, the floor surface should be maintained as smooth as possible and should not involve any sudden drop.

I hope that above mentioned points may help you in effective handling of chlorine, and to avoid spillage & leakage.

Many thanks to all who contributed to this query!

If you have further information to share on this topic, please send it to Solution Exchange for the Disaster Management Community in India at se-drm@solutionexchange-un.net.in and/or to Solution Exchange for the Water Community in India at se-wes@solutionexchange-un.net.in with the subject heading RE: [se-drm][se-watr] Query: Pipeline Damage and Chlorine Spillage-Assessment and Handling – Experiences; Advice. Additional Reply."