Reaction in Waste Container - Leading to Major Evacuation

Jari Henriksson, MSc, Oy Forcit AB; Hanko, Finland

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Abstract:

This paper gives an overview of the incident in Vihtavuori Finland that started the 9th of July 2013. A 1 m^3 bulk container that came from a customer site including sensitized waste matrix and pyrite started to generate steam after one year of storage. The incident lead to a major evacuation due to unknown content of the containers adjacent to the one steaming. After the incident many different actions were taken. This paper describes the actions taken by the company on-site, in logistics, in training and instructions and in crisis response. This is the first public presentation of the incident now that the legal process has been finalized.

1. Introduction

The beginning of July 2013 was warm, sunny and generally event-free. It was the middle of the Finnish summer and many Finns were on their vacation. At midnight July 9th, 2013 the guard made his round at the Forcit facilities in Vihtavuori plant area – as he did every night. In July the sun barely sets so he did not need his flashlight. As he approached the storage building 312 – situated inside a barricade - he noticed a whiff of white steam rising from one of the IBC containers placed along the corrugated steel shed. This being an odd phenomenon he decided to contact the company engineer on call.

This phone call started an event that resulted in a major evacuation, media frenzy, a five-year legal process, updated regulations, changes in procedures and some steam. No injuries - but a lot of learning.

The circumstances leading to the event were multiple. The years prior to 2013 had been good – volume of produced emulsion matrix had increased strongly. The issues that generated some worry were that matrix was not as stable as the earlier recipe. It worked fine, but it left some residue in tanks and IBCs that later crystallized. The tanks and IBCs had to be cleaned which generated more waste than could be handled in the on-site burning grounds, hence IBCs started to accumulate adjacent to building 312 exceeding the permitted storage volumes. There was extra effort in handling the containers; a building to clean them, a filtering device, more people etc – but the storage of IBCs kept growing.

It is important to clarify that there was a wide variety of IBCs – some were almost empty, just some residue on the inner walls, some were full of cleaning water with small amount of matrix, some filled with almost pristine matrix with some crystals in it, some with a cocktail of matrix and other stuff.

As it became obvious that on-site destruction capacity was not enough, additional destruction capacity was acquired from a company outside Finland. Cross-border transfer of classified waste is regulated; hence time was needed to get all the proper permits necessary. In the beginning only modest volumes of waste IBCs were transferred abroad. New permits were needed when the original amount was reached. Ever higher volumes were submitted and subsequently permitted.

Additional storage space had been planned. A proposal had already been submitted to the Finnish authorities – we were eagerly waiting for the permit to start the construction work.

There were many things that should have raised our eyebrows. The growth of volumes, the crystallization of matrix, the residues on IBCs, the variation of content (water, matrix, other) and above all that we were not in control of the situation. We were on a slippery slope, creeping normality or a frog in a pot – we did not see the danger clearly.

2. Incident

The incident itself was relatively uneventful. The guard noticed that the IBCs was emitting steam, this continued at a constant rate until the Finnish military could shoot a hole and insert a water hose to the IBC. There was no explosion, no fire, no personnel or material damage and only very small and local environmental impact.

But - the situation was extremely tricky due to our lack of knowledge. We did not know the exact contents of the IBC. There had to be something generating energy – most probably ammonium nitrate that for some reason had started to decompose. The reason could be some sort of contamination. We did not know the origin of the IBC and how long it had been there. The IBC was in the middle of rows of IBCs placed wall to wall – totaling circa 200.

Our engineer on call informed the technical director of the company who in turn informed the SHEQ director. The emergency services were alerted. After the arrival of the fire chief – who took charge of the rescue mission, a command center was initiated outside the plant area. Although in the beginning our own personnel stayed at our office with a video link to technical director who was located at the Hanko plant, 350 km away.

The fire chief demanded an expert opinion on the situation – how much explosives are there and what is the worst-case scenario. It took some time to make the calculation – partly due to lack of expertise on-site and partly due to lack of information on the content of the IBCs. At that point the fire department had a drone at their disposal, hence an accurate count of IBCs could be made – but the drone could not be used to evaluate the content of neither the steaming IBC nor the IBCs adjacent.

The worst-case scenario was based on that all 200 IBCs contained sensitized emulsion and that all IBCs would be filled to the brim (ca 1 metric ton each) and that IBCs would not contain any excess water and that all of IBCs would detonate – simultaneously. In hindsight this sounds extremely unlikely, but during the night when there was not enough information it was the only option. What we did not realize immediately was that the fire department considered a domino effect.

At the Vihtavuori site there are other companies – which also operate in explosives industries. One of the companies have a nitration unit with acid handling and storage. The fire department made the judgement that the blast would damage the distillation column generating a cloud of nitric acid travelling towards the village ca 1 km away. Therefore, the fire chief decided to declare an evacuation zone of 1.5 km based on his judgement and the possibility of a domino effect; this encompassed the village of Vihtavuori with 2,500 inhabitants. With the majority of the population at school/work, this resulted in the evacuation of 450 people. This evacuation was declared 8 AM – circa 8 hours after the guard noticed the steam.

The declared evacuation was so extreme that a lot of extra resources were needed from Police, and it took some hours before the evacuation was completed. It was also apparent that the “event-free” July was over and all journalists available were eager to report about this event. The media generated an additional level of stress to all involved. Due to the vacation period we could not reach all necessary personnel.

As the IBC generated a constant rate of clear white smoke, we knew that a risk of explosion is still quite low. There was something happening inside the IBC that generated heat and boiled the water in the IBC. We did not know how much water there would be. We knew that when the water would be exhausted – the decomposition of ammonium nitrate would accelerate further eventually leading to some sort of energy release. When water would be exhausted – we should see the steam turning brown or orange.

Figure 1. Storage building 312 (ANFO storage) and the placement of the IBCs – the IBC generating steam is marked with an arrow.

The fire department called for a drone that had an excellent camera but no thermal imaging capability. At that time neither the Fire Department nor the company had a drone. Since then drones have become more available – also on-site. One of the fire fighters climbed over the barricade to measure the temperature of the IBC – it was still below 100ºC – at least measured from the top of the IBC. Because the flow of steam stayed about the same during the day and the steam remained white, we made the conclusion that decomposition rate of ammonium nitrate was still quite low, and IBC contained some water. The drone was flown over the IBCs on regular intervals to check the color of the steam.

Figure 2 Thermal image of the IBC – green cross indicates the IBC.

It also became obvious that we needed an action plan. It might be that the decomposition would end at some point but then again, it might not. Finnish Defence Forces were contacted. They had EOD (explosives ordnance disposal) capabilities in Ähtäri – about 130 km away.

As the IBC was generating steam – at a constant rate – a lot was happening. The people of Vihtavuori village were being evacuated, authorities and Forcit made public announcements, all journalists were calling everybody, stories were published, and social media discussions were rampant.

The plan was to get cooling water sprayed on the IBC first and when the Defence Forces robot arrived to punch a hole on the IBC and fill it with water cooling the reaction. This would most probably cease decomposition of ammonium nitrate. We deemed that there would be a high risk of detonation if we would move the IBC out from the row because there would be additional mixing that would likely increase the rate of decomposition. The IBCs were so close to one another that we also realized it would be impossible to move that one IBC from the row.

Figure 3. IBC is cooled with water

Figure 4. IBC transferred – water hose attached. Still just steam.

As the situation outside the gate seemed chaotic with the evacuation and media frenzy, inside everything was calm and professional. As soon as the Defence Forces robot was on site and the plan was set to action, the situation got better very quickly. The steaming reduced and eventually the fire department started to move the IBCs from the rows and nearing the reacting one. As the IBC was full of water it had cooled, it was moved, and the content emptied to several 50-liter plastic buckets –containing mostly a sludge of matrix and some mineral.

As we could now see the markings of the IBC it became obvious where the IBC came from and that the mineral was pyrite. Those familiar with reactive ground knew that in suitable circumstances ammonium nitrate decomposes in contact with fresh pyrite.

Situation was resolved during the evening of the 10th and the evacuation ended around 9 pm. The event lasted around 20 hours. As the fire department had a rotation system for personnel – we did not. Exhausted we went home to wait what the repercussion might be – individually and for the company. On the other hand, we were happy that nothing serious happened, nobody got hurt.

3. Investigation

The following day together with Forcit, the Police and Tukes (Finnish Safety and Chemicals Agency) the investigation was initiated. There were several lines of investigation:

- what happened – chemically?
- what did the company and people involved do prior to the incident – ie. was some sort of mismanagement leading to the situation?
- was the incident handled properly?
- what could be learned from the incident?

One 50-liter bucket containing mostly a mix of matrix and pyrite had continued to react during the night, see figure 5. There seems to have been relatively extensive amount of heat generated because the material and bucket ended up being quite charred. The material was studied very meticulously by hand – every bit was studied. The findings were somewhat alarming – there had been two RDX-based boosters (ca 25 grams each) inside the IBC. There were also filter bags (jute) and a lot of pyrite.

Figure 5. The 50-liter bucket with matrix and pyrite – clear signs of continued reaction

Initially the police were leading the investigation but also the Finnish Safety Inspection Authority had major role and as usual – they made their findings public. Below is a direct quote from their report.

"*In Vihtavuori, Laukaa, a hazardous situation occurred on Wednesday 10 June 2013, when the temperature began to rise of a container holding residual explosive waste stored in the yard of a storage facility. The container was one of more than 200 similar containers stored in the yard, all of which contained explosive waste. The adjacent storage held 40 tonnes of explosives. The situation was deemed so grave that the Rescue Services decided to evacuate the central Vihtavuori area and restrict road, rail and air traffic in the vicinity of the factory area. Approximately 21 hours after the rise in temperature of the container had been noticed, a rescue crew managed to cool the container down and move it to a safe location. No fire or explosion occurred.* ***The residual explosive waste had originated from a mine. In the mine, positioning of charges in boreholes from below had failed, resulting in the liquid emulsion explosive spilling onto the floor of a tunnel. While cleaning the spilled explosive, the miners accidentally collected detonators*** **(boosters, authors note)** ***lying on the floor, as well as rock formed of fine powder mixed with water****. The residual explosive waste thus created was transported to Vihtavuori, to be disposed of there by the manufacturer. At the time, the factory already housed hundreds of containers of residual explosive waste, all returned by customers. This caused the time for the disposal of this particular container to be brought forward. The heating of the container was detected one year from the incident in the mine.* ***The heating process was caused by a chemical reaction in the mix of explosives and rock powder (*** **reactive ground, authors note*****)****. In breach of the licensing terms, neither the operating procedures of the factory itself nor the authorities responsible for monitoring intervened in the storage of containers holding explosive waste. On the basis of previous experience, the heated container was treated with due caution during the rescue operation.* ***At the beginning, representatives of the explosives factory were unable to provide the Rescue Services with the information they needed on the nature of the chemical reaction and the potential risks posed by the heating process, all of which delayed the rescue operation****. The evacuation of the large area was hampered by a lack of plans and instructions. Finland has no previous experience of evacuation operations on this scale. The Safety Investigation Authority recommends that the Finnish Safety and Chemicals Agency develop a monitoring process and maintain online monitoring registers to enable real-time interaction and monitoring. The Finnish Safety and Chemicals Agency should require that the facilities it monitors produce functional and documented procedures for the detection, assessment and correction of nonconformities, and that all defects detected by the authorities be handled in line with such procedures. These monitoring procedures should also include clear criteria by which authorities must take coercive measures rather than resort to the provision of advice, the conducting of negotiations or the issuance of orders.* ***The Ministry of the Interior should ensure that guidelines be prepared for the implementation of large-scale evacuations*****.**" (bolding made by the author of this article).

The reasons leading to "residual explosive" originating from the mine are not discussed here at length. It is although imperative to note that the personnel at the mine were not properly aware of the reactivity of the pyrite and matrix, they were equally unaware of the proper packaging procedures.

As the Safety Inspection Agency findings mention, these actions were directed to The Finnish Safety and Chemicals Agency not towards the company – this is normal procedure. Safety Inspection Agency address safety recommendations to the appropriate authorities and other agencies and are not conducted to allocate legal liability.

Because the evacuation was according some sources, the biggest “after the war”, the rescue services has a separate seminar to discuss about the incident and learn from it. The subjects varied from communication to the role of the voluntary organizations in providing care to people being evacuated. The company representatives’ role was merely to listen partly due to the initiation of the legal process.

4. Actions

From multiple investigations and discussions, we recognized various actions to perform. These actions can be divided in following themes:

- On-site
- Logistics, to and from
- Training and documentation
- Customer sites
- Emergency response

4.1 On-site

On-site actions in Vihtavuori were multiple. Already prior to the incident a permit process was initiated for a storage area for waste containers. The permit was being processed by the authority and was granted right after the incident. Some preparatory work had already been done, but now we could make the construction as a priority. The paved storage area was equipped with video surveillance connected to the guard office and high capacity water line. It was also decided to place the IBCs so that they would be easy to monitor with a thermal camera and eventually to remove with a fork lift. The decided formation was to place 8 IBCs in a group of 2 by 2 by 2. There would always be two sides of the IBC visible.

Because the IBC involved in the incident had been on-site for more than a year it was decided that there would be a maximum storage period for any IBC. Initially this was difficult because we had a substantial inventory of IBCs that we had to process. Because of this excess inventory a lot of effort was made to get these IBCs destructed safely and swiftly. We negotiated with the authorities who eventually granted the cross-border waste transportation permit and we made an action plan with the receiving party who took care of the destruction. It took circa 9 months to transport and destruct the old IBCs that had been in storage prior to the incident. Because the logistics (described later) was more rigorous, we started to know what we had on-site and could act accordingly. After we had clearly marked and sealed the IBCs, we could send a waste delivery as soon as the truck load was ready. Different category of waste had separate transport, 1.1 and 5.1, truck load was 16 tons and 30 tons respectively.

There were some ideas that did not work. The fact was that many IBCs had a lot of water – could be up to 90% - made us think that we could somehow filter it. The destruction of an IBC that contains 90% water is a major ordeal – a lot of extra fuel is needed. We built a filtering device that worked in principle, but we deemed the handling of IBCs was a hazardous enterprise. Lifting the heavy IBCs needed a robust lifting device but most of all we were nervous that turning an IBC upside down could start some “decomposition process” inside it. It is important to remind that we could not be sure of the IBC content to an acceptable level – at least concerning the IBC from prior to the incident.

Emulsion breaking was tested but at least initially the waste problem would multiply. We realized that if we would break an emulsion that had a lot of excess water, it would generate a water (nitrate) phase with traces of oil and oil

phase with traces of nitrate. Nothing that could be easily disposed, hence emulsion breaking was discarded – for the time being.

The new storage area with neatly positioned groups of IBCs would be regularly visited by the guard. The IBCs temperatures and physical appearances would be monitored. If there would be any change the IBC would be destructed immediately on-site instead of any transportation.

We also realized that we had many IBCs that were either very close to being outdated or already passed their approval date. The IBCs approval date can be extended but the cost and approval process are not very economic. Therefore, the IBCs had to be destructed. But the problem was that if the IBC is out-dated it is not approved for transportation. Some of these IBCs were transported with extra precautions and permits but majority were destructed on-site. These precautions included careful route planning and informing all Fire Department along the route.

The actions described here concentrate on what was done to enable a safe and rigorous procedure of handling the IBCs. There were multiple actions regarding the plant operations. The production process was reviewed and waste generating situations identified. The focus on minimization of waste resulted an annual 25% waste reduction for few years. This process is still ongoing – we regularly review the waste generated and every time we find new ways to reduce the waste - the low hanging fruits have been picked though. There is still work to be done especially for cartridge production.

One problematic issue prior to the incident was that matrix was sticking on all tank walls generating a surface that after drying could fall on top of the matrix and clog pumps and charging hose. Already prior to the incident we had made a change in the matrix formulation reducing the matrix sticking to wall surfaces. This formulation modification eventually reduced the waste generation substantially as it was taken into use on all sites. It is important that development process of a recipe change is done properly. A new recipe needs to be tested extensively to gather information of long-term effects on equipment and tanks.

4.2 Logistics

Prior to the incident most of the matrix logistics was conducted with IBCs – they were deemed cheap and easy to use. The drawbacks became obvious quickly. The more wall area the more cleaning was needed, and more waste generated. Therefore, we made the decision to minimize IBC logistics and prefer dedicated transportation tanks that would be used to transport the matrix from production site to the customer site, that would also have a proper tank.

Because Vihtavuori site acted as a hub for all internal matrix waste – some sites sent shipments either very rarely in IBCs that contained old matrix or IBCs that contained only small amounts. Therefore, we acquired different vessels for smaller amounts to have properly filled vessels and to discourage using the vessels as garbage bins. The ADR acknowledges a wide size range of vessels that can be used for this purpose.

All IBCs originating from customer site had to be marked and sealed. We applied the procedures of Track&Trace directive. A detailed book keeping of the IBC was imperative. Some time later we started to weigh all IBCs.

During the incident the media asked about detailed knowledge of the container content. As an engineer the answer to this simple question was that we did not know. The fact was that to us it was not possible to fully check the content of the IBC just by looking inside or just the outside of the IBC. A full check would have required a thorough inspection, by hand, as the IBC involved in the incident was inspected afterwards. This was clearly impossible – hence the answer, which was not the most PR-friendly answer – but the truth.

4.3 Training and instructions

As we had trained all involved personnel prior to the incident we still felt that the instructions needed to be reviewed and all personnel handling waste in all different stages needed to be retrained. The instruction review was necessary due to all new information regarding off-spec matrix, possible contamination and our own internal guidelines to shorten the process from generation to destruction. We also wanted to minimize all possible contamination in every single stage of handling.

One key person in the transportation chain is the individual preparing the IBC for shipment. The key task is to classify the shipment as either 1.1 (sensitized) or 5.1 (unsensitized). If there was a slightest suspicion that the content is sensitized the classification need to be 1.1, the IBC need to be transported accordingly and in the internal process handled more quickly that an IBC with a classification of 5.1. Another key issue was possible contamination. It was imperative that nothing other than matrix was allowed in the IBC. Of course, this is impossible, but making clear that no contamination was allowed, the personnel was becoming more respectful of the material they were processing. We quickly saw a decrease of amount of "other stuff" in the IBCs. One noteworthy incident prior to 2013 was when we realized one IBC containing something extremely smelly. It was the content of one or more portable toilets – as a result all personnel involved were sent to get hepatitis shots. It still makes one sad to realise that there was a total disrespect of the material returned to Vihtavuori. Fortunately, this was an isolated incident, but the inventory of stuff that was found in the IBCs was interesting; pants, shoes, spray cans, gloves, all kinds of rubbish, etc.

The mix of matrix and pyrite was tested by Finnish Defence forces. They heated the mixture and booster (primer) separately in excess of 200°C without any detonation. It can be argued that the mixture in the IBC could not have detonated. But of course – this is speculation.

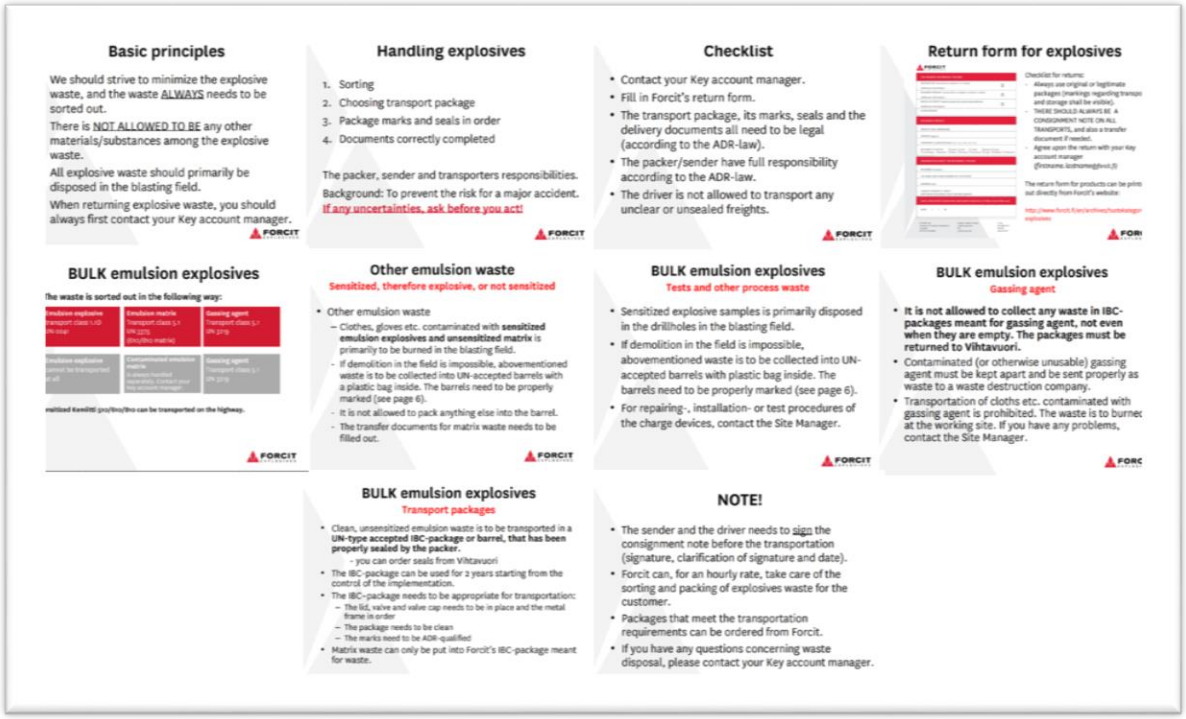
Instructions will not work if there is no enforcement. We started to invoice steeply customers who did not follow the rules. There is a monetary incentive to follow the rules.

What still makes us baffled is the fact (at least according to authorities) that the original classification is holy. We are not allowed to change the classification of the IBC from 5.1 to 1.1 even if we see that the content is 1.1.

4.4 Customers

The off-spec material was generated at the customer sites from material delivered to them from us. Depending on setup at the customer site, some material was used by us, by the customer or by a third party. It is important to note that all matrix processed before and after the incident was of our own produce. We never handled any material originating from another explosives manufacturer – this was and is prohibited by the Finnish environmental authorities. Because so many different parties could be involved it was decided to review all instructions and training material.

Figure 6. Selected training material concerning bulk emulsion off-spec as of 2014.



Adding bureaucracy was an effort to nudge all stakeholders to take the waste issue seriously. By adding stages, checks and paperwork we were hoping that it would be eventually easier to take precautions not to generate excess waste. It would be easier to plan how much matrix a site would need, thus reducing the return material. Even though this material would have been good for reuse somewhere else, there was still the element of quality risk. Adding the element of extra cost, it also became interesting to the site management.

In matrix logistics there are multiple transportation and storage tanks, piping and pumps. There is a need to periodically clean all tanks and equipment. Prior to the incident the cleaning routines were haphazard and water usage was not controlled. The cleaning was conducted with operators whose primary job description was something completely

different. As soon as professional cleaning personnel and equipment was utilized the amount of water used and eventually ending up in IBCs was reduced dramatically. This reduction made also destruction easier. The burning of emulsion waste needs a lot of extra fuel (wood, dry twigs etc.). It also showed that proper cleaning, with pressurized water, made the tanks walls cleaner pushing forward the need for next cleaning. Obviously, the recipe change played a role in extending the cleaning interval.

4.5 Response

The persons involved in the incident – from our company – were internally criticized for being too open to the media. The author of this article still disagrees. Some of us had had some PR training and knew that an open communication is important. We tried to answer to all calls, we had press releases and participated in the combined conferences with the authorities. The author argues that the open communication policy made the story die down relatively quickly – all questions were answered, there was nothing more to write.

After the incident we realized that our internal communication procedures still had to be reviewed. Some additional training was also provided – although the "training" during July the 10th was far better and more intense.

As Seveso directive states, sites like Vihtavuori need to have a major emergency training annually. Since the incident we have had more focus on communication issues. We measure the time taken for initial internal information and how well the communication procedures work in practice.

One issue remains, an incident of this calibre – were nothing really happens but the pressure is constant – people start eventually to run on adrenaline. We did not have the seemingly unlimited resources of the Fire Department, but we could manage. What would the situation have been if someone would have gotten hurt or even worse? When something eventually happens, we need more people than we think, and we do not necessarily see that we need help. In this case, our personnel called in asking if we needed help – to this day, this makes the author glad.

There are many other actions that we did and will do in the future. We have tried to list all the major ones in this article, but there is one remaining observation. It is difficult to know in advance how one functions in crisis – some may freeze completely, some fall back to their training as some will adapt. It became apparent to the author of this article that all practice we have had during the years paid off and that we have personnel who are able to adapt.

5. Five years later

The investigation of this incident was wide – multiple persons were investigated and subsequently charged from our company, the company sending the IBC and persons representing the authorities. After five years all legal processes were finalized. Only two persons received small fines. The process took a long time due to its complexity but also due to some delays in prosecution.

Currently the percentage of off-spec matrix is low, everything can be processed relatively quickly on-site or at the contractor site. Waste inventory is kept low by regular transportations to contractor site – even shipment that are not "full" yet will be shipped away. We want to process the off-spec material sooner rather than later.

There has been some internal discussion of recycling the matrix to virgin material, at least if the matrix quality is good. The author of this article disagrees strongly. We do not want any source of contamination together with matrix and we do not want anything to compromise matrix quality. It is more fruitful to concentrate efforts in waste reduction. The rework quickly becomes surprisingly costly and the safety can easily be compromised.

6. Take home message

There are two major messages that the author wants to highlight. The first one is the dangers of creeping normality, the fact that small incremental changes may mask the major risk lurking around the corner. In this case the changes were the increasing volumes, in many instances referred to as a positive problem, and the fact that the matrix was not stable.

The other message is to get rid of matrix waste as soon and as effectively as possible. Recycling is not the answer due to added safety risks from contamination. It is more efficient to minimize the generation of off-spec matrix.