Oil spill from a sub-surface connection pipeline

28 February 2012

Wesseling

Germany

Release
Pipeline
Hydrocarbons
Corrosion
Pollution clean-up

THE FACILITIES INVOLVED

The site

The Rhineland Refinery, located in the south of Cologne is with its crude oil processing of 16 million tons per year, the biggest refinery of Germany. It covers an area of 440 hectares. In the year 2002, the refinery was formed by fusion of two oil companies. 1600 employees are working in the refinery.

The southern factory in Wesseling (Figure 1) mainly manufactures aromatic substances, olefins and methanol besides mineral oil products. This factory has produced fuels since 70 years. These fuels and other liquid products are stored inter alia in a tank field in a south western area outside the refinery (Figure 1). The Wesseling refinery is an upper tier Seveso establishment.

Figure 1: The Refinery south of Cologne is connected to the tank field (down left) by sub-surface pipelines

The involved unit

The refinery is connected with the tank field by a sub-surface set of 8 pipelines. As they belong and are managed by the refinery, they are part of the Seveso establishment.

The single walled steel pipelines are used for the transport of mineral oil products and other fluids hazardous to the environment. Pipeline number 7 was used to transport kerosene (Jet A1) from the refinery to the tank field. At the location of the leakage it is situated about 3 to 4 meters underground in sandy soil.

Four of the pipelines including number 7 were constructed in 1942 and are without traceable permits from that time. In 1986 the pipeline was in a good state and in conformity with the valid regulations, as was certified in an acceptance test report. In 1987, a permit was given to a new pipeline for waste water within this pipeline corridor. In that permit the ongoing allowance of the other pipelines was stated. After a relevant change of the tank field in 1994, the pipeline for the transport of kerosene (number 7) was also mentioned in the permit.

To be in compliance with the German regulation on inflammable liquids that was valid at that time, the pipeline had to be equipped with facilities to compensate too high pressure and a leakage detection system. Alternatively to the latter, tightness checks had to be performed to proove no loss of containment. In addition, regularly tests of the protective cathodic potential of the corrosion prevention system were necessary.

The safety equipment of the pipelines was in compliance with the regulation. The leakage detection system was able to register 5 % of the maximum flow of 100 m^3/h of liquid which is 5 m^3/h. The latest tightness and pressure tests from 2008 and 2010 showed that there were no problems concerning pipeline 7 and the other pipelines. In addition, every 3 months tests for the control of creep leakages were performed.

Until 2007, all yearly tests of the cathodic corrosion protection system confirmed protection without error. From 2008 on this was no longer the case. At least for some parts of the pipeline the protection could no longer be confirmed.

Technical data of pipeline number 7

- Length: 800 m
- Type of pipeline: steel, single walled, sub-surface
- Maximum operating pressure: 13,8 bar
- Internal width: 100 mm
- Pump rate: 100 m^3/h
- Fluid: Jet A1 (kerosene)
- Corrosion protection: electrochemical (cathodic), bitumen layer

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident

On Saturday 25 February 2012, obvious changes of the filling level of two tanks at the Wesseling site of the refinery were observed. As cause a leakage of the connecting pipeline number 7 was assumed and verified by pressure and leakage checks. The pipeline was blocked on 26 February and discharged on 28 February. The location of the leakage outside of the tank field and the refinery was identified by noise emission analysis and verified by digging up (Figure 2). It was shown by later calculations that, over a time period of 28 days, 846 tons (or 1057 m^3) of kerosene were emitted into the soil. The leakage rate was below 2 m^3/h (0,5 l/s) and could not be detected by the installed leakage detection system because it was only able to detect a minimum flow rate of 5 m^3/h (1,4 l/s).

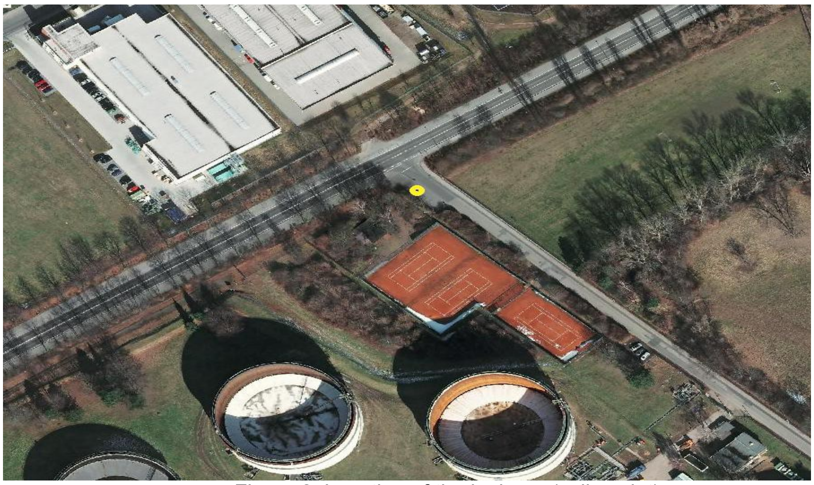

Figure 2: Location of the leakage (yellow dot)

The consequences of the accident

The spoiled kerosene contaminated soil and groundwater in an area of about 50,000 m² (5 ha). The spreading on the groundwater was only stopped after 4 remedial stand pipes were taken into action. With these stand pipes the layer of kerosene on the groundwater and contaminated groundwater are removed from the soil. Up to 1 January 2015 about 280 m³ of kerosene were removed from the soil. For the further clean up, chemical and biological measures are under consideration.

Fortunately the ground water of a nearby drinking water works is not affected by the kerosene spill because of the opposite ground water flow direction.

The European scale of industrial accidents

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in February 1994 by the Member States Competent Authority Committee for implementing the 'SEVESO' directive on handling hazardous substances, and in light of the information available, this accident can be characterised by the four following indices:

The parameters composing these indices and their corresponding rating protocol are available from the following Website: http://www.aria.developpement-durable.gouv.fr

The "Hazardous substances released" index was scored a "3" as a result of the 1057 m³ of kerosene that spilled out "Parameter Q1".

The "Human and social consequences" was set equal to "0" because no consequences of this type were observed.

The "Environmental consequences" index was assigned a "3" because of the contamnation of soil and groundwater in an area of about 50,000 m² "Parameter Env13".

The "Economic consequences" was left blank due to a lack of data on this indicator.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The kerosene pipeline connecting the Wesseling part of the Rhineland refinery and the tank field was protected by two different anti corrosion measures: an outside bitumen layer and an electrochemical cathodic corrosion protection system. These measures are of course without effect against inside corrosion but there is no known inside corrosion stemming from kerosene.

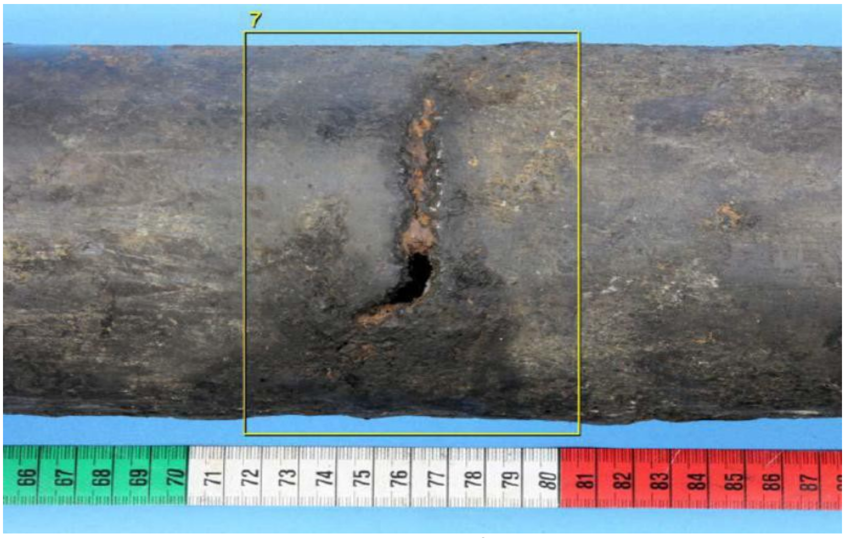

Figure 3: Hole in the steel kerosene pipeline stemming from outside corrosion (copyright: operator)

After the loss of kerosene and the detection of the leakage location the damaged part of the pipeline was brought to a laboratory for further investigation. The outside bitumen layer had been “washed” away by the kerosene flow. A hole in the steel pipe with an area of about 70 mm^2 caused by outside corrosion was found (figure 3). There were only minor signs of inside corrosion stemming probably from former more corrosive fluids transported in the pipeline but they had no effect on the integrity of steel construction.

In the direct vicinity of the kerosene pipeline, a crossing drinking water pipe was found (figure 4). It was also protected against corrosion by an outside layer and a cathodic potential. At the location of the kerosene spell there was a damage of the outside layer of the water pipe. Below the damaged layer the steel water pipe showed no signs of corrosion. In contrast to the case of the kerosene pipeline the cathodic protection against corrosion had worked at the water pipe. The electrochemical protective system of the water pipe was not connected to the oil product pipeline trass. Instead it was connected to protective system of the tank field. So, it was assumed that a difference in the electrochemical potentials of the two steel pipes caused the corrosion of the kerosene pipeline.

To verify this assumption, other parts of the sub-surface kerosene pipeline were put under investigation. Damages of the outside bitumen layer were also found at other locations. After removal of the bitumen layer at these parts of the pipeline no signs of outside corrosion were found. This verified the assumption that the two barriers system of protection against corrosion had worked under normal conditions but not in vicinity of the steel water pipe with a different electrochemical potential. As a result, it has to be assumed that the potential of the steel kerosene pipeline had become positive against the potential of the steel water pipe. As a consequence outside corrosion of the kerosene pipeline took place and resulted in the leakage. This could only happen because there was a damage of the outside bitumen layers of the kerosene pipeline and of the water pipe at locations very close to each other.

Because of the tiny hole in the steel pipeline (about 70 mm^2, Figure 3) caused by electrochemical corrosion, the low temperature and discontinuous kerosene transport processes the leakage was only detected after 4 weeks. Calculations of the leakage rates under pressure during the transport of kerosene to the tank field and under standstill conditions are shown in table 1. Unfortunately the pipeline was not blocked at times of stand still with the consequence that at these times there was a big contribution to the kerosene pollution of the soil.

Table 1: Calculation of the kerosene amount spilled into the soil

Period of time under transport pressure 152 h:	375 m³
Stand still with only hydrostatic pressure 448 h:	682 m³
Sum:	1057 m³ (846 t)

Figure 4: Water pipe (at the top of the picture) crossing the kerosene pipeline (copyright: operator)

ACTIONS TAKEN

As connection pipelines today have to fulfill the requirements of the regulation on installations handling substances hazardous to water and the safety operation regulation in Germany, the first action was to guarantee that the technical requirements are met. Today, double walled sub-surface pipelines are regarded as best available technique for transportation of fluids hazardous to water, but single walled pipelines enjoy preservation of the status quo if additional safety measures are applied. To guarantee the application of these contingency measures, the competent inspection authority (Regional Government Cologne) sent an ordinance with obligations that had to be met by the operator of the pipelines.

Before the re-use was allowed, a so called zero-measurement had to be carried out for all pipelines. For this a 100 % scrubbing of the pipelines for the determination of the wall thickness was necessary. At locations were scrubbing was not possible, contingency measurements had to be carried out to determine the wall thickness. The results from the scrubbing had to be used to calculate the life expectancy of the individual pipelines to guarantee a safe operation during the next ten years. This procedure has to be repeated every five years. Additional demands that were based on the German technical guidelines for sub-surface pipelines were :

- installation of a sophisticated leak detection device;
- yearly tightness tests;
- daily inspection of the pipelines corridor;
- lock of the pipelines at standstill times.

As the interference of the steel kerosene pipeline with the steel water pipe was main reason for the leakage, the operator changed the steel water pipe into a plastic pipe. To improve the cathodic corrosion, prevention the system was disconnected. The part in the vicinity of the tank field was connected to the electrochemical system of the tank field and electrically isolated from the other part of the pipelines corridor. In addition, the map containing all pipelines was reviewed to identify all pipeline crossings. An intensive measurement was carried out to identify all locations with disturbances of the electrochemical potential. At these locations the soil was removed and the bitumen coating renewed where necessary.

Meanwhile, the operator has decided to change to an above-surface pipeline connection between the production site and the tank field because the installation of a sophisticated leakage detection system is very laborious. A further advantage of this decision is that the pipelines corridor will be in compliance with the best available techniques in the future and the risk of further soil contaminations is considerably reduced.

LESSONS LEARNT

In an expert report on the damage evaluation, the following measures for the future handling of single walled underground steel pipelines were recommended:

- baseline measurements for the calculation of wall thickness reductions;
- involvement of the pipeline maintenance staff in building activities in the surrounding of pipelines;
- improvement of the leakage detection device;
- improvement of the cathodic corrosion protection device;
- faster remediation of detected deficiencies in the cathodic corrosion protection device.

Even if there are redundant protective measures against corrosion like bitumen coating and electrochemical protection, a leakage of a single walled pipeline cannot be excluded. Especially when there is other infrastructure equipment of the production site that is also electrochemically protected, differences in the electrostatic potential followed by increased corrosion can occur. The danger of interference with other equipment is even higher when part of the pipeline is located outside the production site and not all sub-surface building activities are identified by the operator.

Single walled sub-surface connection pipelines are no longer best available technology. The best option is to remove and substitute them by double walled or above ground pipelines with a second barrier against soil pollution but this is normally very expensive. For this reason single walled sub-surface connection pipelines enjoy preservation of the status quo when the integrity of the pipeline is guaranteed by contingency measures.

First, a so called zero-measurement has to be carried out that means a 100 % scrubbing for the determination of the wall thickness over the full length of the pipeline is necessary. At locations were scrubbing is not possible contingency measurements are necessary to determine the wall thickness. The results have to be compared with former measurements to calculate the corrosion rate and the life expectancy of the pipeline to guarantee a safe operation during the next ten years. This procedure has to be repeated every five years.

As already mentioned, the cathodic corrosion prevention system is sensitive against outside electrochemical interferences. To avoid this, maintenance staff has to know all the activities in and outside of the production site that can have an influence on the electrostatic potential of the pipeline. In addition, intensive measurements along the pipeline have to be carried out regularly to identify locations with interferences or damaged coatings. Needless to say that at these locations the necessary measures have to be taken.

The leakage detection device was only capable to notice leakage rates of at least 5 % of the maximum flow rate which means 5 m^3/h. As the leakage rate was lower than this because of the tiny hole the oil spill was not detected for a long time. In addition the pipeline was under hydrostatic pressure from the storage tanks during transportation breaks because the valves were open at those times. As a consequence kerosene also spilled into the soil during these breaks. To avoid this in the future the expert report on the accident gave the following advice. The leak detection device should be able to notice:

- 1 % of the maximum flow rate at times of transport;
- 10 - 50 l/h at times of stand still;
- Less than 5 l/h for creeping leakages.

The lock of the pipeline during times of stand still is an additional measure to reduce potential soil pollution.

Pressure and tightness tests on a yearly basis and additional tightness tests on a quarterly basis as demanded by the German technical guideline for subsurface pipelines as an alternative for a leakage detection system are not sufficient to avoid a massive leakage as is shown by this case. This is another lesson learnt form the accident. The German technical rules and standards only contain weak requirements concerning the operation prolongation of subsurface single walled steel pipelines transporting fluids hazardous to water. There are no requirements on the capability of leakage detection devices, and only a few control measurements are required for the assessment of the remaining lifetime. As a consequence the competent inspection authority has to induce the necessary control and maintenance measures by administrational order. This only works if the operator agrees or after an accident. For this reason, the revision of the concerned technical rules and standards was initiated.