Case report

Accidental contamination of a German town’s drinking water with sodium hydroxide

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A B S T R A C T

Case report of a very serious drinking water incident putting up to 50,000 inhabitants of a town near Bonn in North Rhine-Westphalia, Germany at risk. A concentrated solution of highly alkaline water by sodium hydroxide was accidentally washed into the town’s drinking water at a pumping station and increased the pH-value of the water to 12. Residents who came into contact with the contaminated water immediately had a toxic reaction. The incident was detected by complaints from customers and after that was stopped within several hours. The pipes were flushed and the customers were warned not to use the water till the all clear. After this immediate management there was an investigation and the cause of the incident was detected as an accidental release of accumulated sodium hydroxide (NaOH) solution. The lack of a network alarm system and the automatic cut-off mechanisms as deficiencies in the design of the station were rectified by the water company immediately after the incident.

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Case report of a very serious drinking water incident putting up to 50,000 inhabitants of a town in North Rhine-Westphalia, Germany at risk. A concentrated solution of sodium hydroxide was accidentally washed into the town’s drinking water at a pumping station and increased the pH of the water to 12. Residents who came into contact with the contaminated water immediately had a toxic reaction. The incident occurred on a weekday in late spring 2013.

This report describes the cause of the incident and the clinical reactions of those affected by the highly alkaline water.

Description of the incident

Shortly after 16:00 on a weekday in late spring 2013 the municipal water company in Bornheim started receiving complaints from customers about the water. It had an odd consistency although there was no unusual smell. The complaints all came from the lower lying area of the town. One of the first complaints was from a man who reported that his skin and scalp had turned red, and he felt pain and a burning sensation wherever he had been in contact with the water (Figs. 1–3).

The water company called in its standby duty team and increased the flow of water through the pipes. At first the water company suspected allergic reactions as a result of the cleaning of the municipal water pipes earlier in the day. Then the standby duty team realised the water had a soapy consistency and they detected a pH value of 11.96. They identified the source as a sodium hydroxide (NaOH) solution. They cut off the supply of this solution and further increased the flow of water through the pipes. In the meantime the company had arranged for the inhabitants of the streets where the complaints had come from to be warned. The police and fire service went door to door advising the residents not to use the water until the all clear. At 22:00 the flushing of the pipes was complete and the pH value was back to normal levels. The all clear was given.

The authors were commissioned by town B to investigate the health aspects and the management of this incident (WHO, 2011; Bundesministeriums der Justiz und für Verbraucherschutz, 2013; Bundesgesundheitsministerium, 2013).

Cause of the incident

An external expert was commissioned by Bornheim to investigate the incident and identify how the accident happened.

The water company uses two different drinking water sources (groundwater and reservoir water) which are mixed at an unmanned pumping station. Diluted sodium hydroxide solution is added to raise the pH value to 7.4–7.6. Sodium hydroxide is an officially approved substance for adjusting the pH of drinking water.
At the pumping station in question soft water held in a 1000 l tank is used to dilute the NaOH solution. A pump boosts the soft water and releases it into the drinking water pipe through a dosing lance. The concentrated caustic soda is usually dosed into the suction pipe of this pump.

The investigating expert believes that due to a clogging of the dosing lance the flow of the diluted sodium hydroxide into the drinking water was interrupted. Since the dosing of the concentrated caustic soda was not stopped, the concentrated caustic soda was pumped backwards into the soft water tank and accumulated there and formed a highly concentrated solution. This could have been prevented with a better designed system and state of the art monitoring.

Earlier on the day of the accident, the dosing lance had been cleaned. When normal service resumed at 14:10 that day, the concentrated sodium hydroxide in the soft water tank was released into the drinking water main pipe and the contaminated water got into the network. The investigation report points out that the sensors in the main pipe only registered the raised pH with a lag time of 60–90 min. Furthermore, the alarm only rang locally (the station is

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**Fig. 1.** Exterior view of unmanned pumping station. As can be seen, it sits in a field.

**Fig. 2.** Soft water tank, black. The concentrated caustic soda was pumped backwards into the soft water tank and accumulated there to form a highly concentrated solution.

**Fig. 3.** Blue marked are the streets with contamination and red the reported complaints. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
in a field and no one heard the alarm), and there was no automatic cut-off, either on the sodium hydroxide pump or on the drinking water pumps.

Due to the length of the pipes (2.2 km) the contaminated water did not arrive in customers’ homes until 15:45 to 16:00. When the first reports arrived at the water company, the duty team investigated various possible causes of the contaminated water. At 17:11 they became aware of the raised pH value. At 17:50 the sodium hydroxide solution dosing pump and the soft water pump were turned off, more than 3.5 h after the toxic solution was released into the drinking water. Altogether the investigator believes the highly alkaline water may have been in the network for 4.5 h.

The contaminated water seems to have reached only the lower lying area of Bornheim. The investigator believes that this was because the relative density of concentrated NaOH solution is higher than water. Therefore it might have settled at the bottom of the pipe, just where the drinking water for the lower lying area is extracted via a T-fitting. Thus we believe the contaminated water was only delivered to 10,000 of the town’s water 50,000 customers.

Toxic reactions due to raised pH levels

When skin and mucus membranes come into contact with highly alkaline water there is a danger of burns. If eyes are involved there is risk of blindness. If ingested it may cause burns in the gastrointestinal tract and intestinal strictures. The risk depends on the strength of the sodium hydroxide solution: the higher the concentration of sodium hydroxide the higher the pH value and the higher the intensity of the burns. The lead author was advised by one of Germany’s national poison centres (Giftzentrale Bonn, 2013) that the relationship is as follows:

- pH lower than 11.5: no burns
- pH between 11.5 and 12: possible burns
- pH greater than 12: definite burns.

Clinical consequences of the incident

First aid in the case of an alkaline burn normally involves flushing the irritant from the skin with ordinary tap water. After this, medical treatment is necessary to avoid severe damage with poor healing of wounds (IFA, 2014; Gunnarsson, 1999; Han, 2011; Ma, 2007). The advice after contact is to wash it for about 15 min. None of this was possible in this incident. In fact the affected people often made the situation worse: they were very confused by the soapy consistency of the water and used yet more water to try to rub the “soap” off. Staff in our laboratory tested alkaline water and found the soapy consistency starts at a pH value of 11. General and specific properties of NaOH are described in the safety data sheet (IFA, 2014).

Six people identified themselves as having injuries as a result of the contaminated water. The lead author was able to interview five of them.

Case report no. 1

Patient no. 1 reported that he started showering at 16:00 and was lathering his body and head when he discovered the soapy consistency of the water. He tried to wash off the soapy water, but then he felt a burning sensation, and blistering started everywhere he had washed, including his eyes and other mucus membranes. He tried tasting the water and felt it burn his tongue. Once out of the shower he noticed his nipples, genital area and mouth were inflamed, and red spots had developed on his skin. He panicked, his heart rate and blood pressure increased, and he called an ambulance. In the ambulance he was given cortisone intravenously and Fenistil®, as well as a Nitroglycerin spray® to reduce his blood pressure. Once he reached the hospital in the nearest town (Wesseling) he was able to take a shower. After discharge he received medical treatment for a further 2 weeks, consisting of decreasing doses of cortisone, an emollient cream, and cortisone eye drops for damage to his corneas.

Case report no. 2

Patient no. 2 reported that she and her husband both drank a glass of tap water at 16:00 after going jogging. The water was in no way remarkable. At 19:00 she took a shower. She could not get rid of the “shampoo” from her hair. Simultaneously she suffered burning and redness in her face and on her shoulders, arms, legs and back. She was so shocked she started to cry, and she told her husband to take her to hospital. When he went outside he saw a crowd of neighbours and the fire service. The latter confirmed that he should take his wife to hospital. The patient reported that it was very painful to put on clothes. They went to the nearest hospital in W. There she took a short shower, as she could not tolerate longer water contact because of the pain. She received an intravenous infusion of cortisone. She was then treated for a further 2 weeks because of multiple open skin wounds. She had no eye problems. The treatment included Soderm lotion® and Ecural cream® (Fig. 4).

Case report no. 3

Patient no. 3 was a surgical nurse. She arrived home at 17:00. She filled a jug with water and washed an apple. She ate the apple without drying it, but had no further contact with the water. At 17:30 a distinct swelling of 5 × 5 cm developed on her upper right lip. She first thought she was suffering from an allergic oedema. She used cortisone ointment and took an antihistamine (Cetirizine®). At 18:45 she noticed the police outside her house. They advised her not to use the water until 20:00. She showed the police her upper lip and was sent to the hospital in W. It is a small hospital with one emergency doctor on duty, so she had to wait as other patients had similar but more serious problems. Her itching eczema disappeared in less than 24 h with further antihistamines and the application of cortisone ointment.

![Fig. 4. Patient no. 2, toxic dermatitis 3 h after contact with the contaminated water and after the intravenous infusion with cortisone, the photographs taken of the other patients show similar skin conditions.](image-url)
**Case report no. 4**

Patient no. 4 came to the water company's attention at a public meeting that was held about 2 weeks after the incident. She reported that she suffers from a goitre and it is recommended that she drink a lot of water. She drinks only tap water. The taste of the water at the time of the incident was not remarkable and because of the goitre her swallowing is always a bit impeded. Two days after the incident she noticed some discomfort when swallowing. The taste buds at the base of her tongue were swollen. The family physician prescribed her antihistamines (Cetirizine®) for 1 week and as the symptoms did not stop she was sent to an ENT physician. Her pathology tests were negative. She later had an oesophagogastroscopy, also with negative macroscopic and microscopic pathology results.

**Case report no. 5**

Patient no. 5 was in Bornheim briefly for work reasons. He reported taking a shower some time between 18:30 and 19:00. He sensed immediately that there was something wrong with the water. He described it as "oily". His scalp started to burn while he was washing his hair. He stopped his shower and informed his landlord. The landlord had just been contacted by the fire service so knew to send his tenant to the hospital in W. The patient showered there and received an intravenous infusion of cortisone. He had eczema for about the next 2 weeks.

**Summary of health impact**

All reported visible health problems occurred immediately. The main reported problem was contact dermatitis caused by an irritant. It was not an allergic reaction (which causes problems only in predisposed individuals) but a toxic dermal reaction (which affects every individual who has sufficient contact with the toxin).

The extent of the damage was determined by:

- the pH value at the time of contact,
- the size of the area of contact,
- the duration of the contact,
- the part of the body in contact (thin skin and mucous membranes are more sensitive),
- the amount of rubbing,
- the use of soap or shampoo (because of the greater length of time in contact with the water, and the reduction in protective function of the skin), and
- whether the water was swallowed or not (ingestion of sodium hydroxide solution can cause severe necrosis with intestinal strictures).

It is important to note that it is not possible for anyone to have received burns in the gastrointestinal tract without noticing it at the time.

**Conclusion**

This was a very serious incident, with 10,000 people exposed to contaminated water and therefore at risk of severe injury. In addition there was the potential for another 40,000 people to receive contaminated water from this pumping station, meaning that a total of 50,000 people were at risk.

When the pumping station was designed and built, the risk of contamination with sodium hydroxide was not foreseen. Such a risk was probably not foreseeable. However, the risk of an accident at the pumping station was foreseeable, so the lack of a networked alarm system and automatic cut-off mechanisms were deficiencies in the design of the station. These deficiencies were rectified by the water company immediately after the incident.

The authors consider that the incident had a remarkably low impact, with only six reported cases of injuries. We believe this is due to the following:

- The water was only just toxic enough to cause harm, with a maximum pH of around 12.
- Concentrated NaOH solution is heavier than water, so the toxic water is estimated to have reached only 10,000 out of the water company's 50,000 customers.
- Few people had significant contact with the water. We assume that the people who reported the water problems but did not report an injury had not brought sensitive skin areas or mucous membranes into contact with the water – for instance they only washed their hands with it. If the incident had happened in the early morning, we expect there would have been more injuries from showering.
- The water company responded quickly and effectively. The problem had not been predicted nor was the cause known at first, so they took standard measures in case of a drinking water problem. The principal measures taken – to flush the pipes and to remove the toxic water on the one hand, and to inform the residents not to use it on the other hand – helped to prevent more serious damage.

Overall it was a very fortunate outcome compared with the possible danger. The town was transparent in its response to the incident, undertook immediate improvements to the pumping station, kept its residents informed, and paid compensation to those affected.

**References**

Bundesgesundheitsministerium, 2013. Incident Guidelines Federal Ministry of Health (Störfall Leitlinie des Bundesgesundheitsministerium), Germany.


