An environmental catastrophe and its incorporation into the environmental engineering curriculum at the University of Pannonia

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ABSTRACT: Red mud storage, Cassette No. 10, ruptured on 4 October 2010 during the daytime in Hungary. About one million cubic metre of red mud sludge burst and covered a territory of about 1,017 hectares. The caustic sludge flooded the surrounding settlements and polluted the nearby Torna stream, which flows through the Marcal and Raba rivers into the Danube. The red mud sludge exhibits alkaline properties, therefore, this environmental disaster resulted in an extremely serious situation. Immediately after the catastrophe, the University of Pannonia, Veszprém, Hungary, set up an emergency response team to carry out environmental monitoring and to devise red mud sludge clean up technologies. This paper deals with the results of the environmental monitoring and the emergency measures taken and with the incorporation of this very serious event in the environmental impact assessment course programme. The key issues of the disaster, the history and the life cycle of the red mud reservoir are explained in detail. The processing and reutilisation of the red mud in order to avoid events like this are also dealt with.

INTRODUCTION

Red mud sludge is a solid waste by-product of the Bayer bauxite processing works and it is highly basic with a pH of about 12-13.5 (sometimes up to 14) [1]. Bayer technology is used for the manufacture of alum earth. During this procedure, the bauxite is treated with concentrated NaOH solution. The bauxite contains alumina in the form of tri- or monohydrates, which are dissolved in concentrated sodium hydroxide solution.

The slurry obtained after the dilution is a mixture of the caustic aluminate and the red mud sludge. The separation of the aluminate solution from the red mud sludge can be carried out in press filters, Dorr settlers or in centrifuges.

According to Hungarian Government Decree No. 240/2005 (X.27.) on the rules of the trans-boundary transportation of hazardous materials [2], which is in harmony with the International Basel Convention of 1989 on the control of trans-boundary movements of hazardous wastes and their disposal [3], bauxite residue (red mud) with a pH < 11.5 is considered to be non-hazardous. In the case of the red mud at the waste disposal site close to Ajka, the pH value of the red mud was higher than 11.5, which is very dangerous for the environment and human health and should be treated as hazardous waste.

The MAL Hungarian Aluminium Production and Trading Company, based near Ajka, is the only company in Hungary processing bauxite and refining the ore to produce alum earth and alumina. During the past several decades, the Company produced products of high quality and parallel to this, a significant amount of red mud and red mud sludge were generated in Ajka. Both dry and wet disposal technologies were used. The red mud and the caustic sludge were stored in cassettes.

RED MUD CATASTROPHE AND ACTIONS TAKEN

The containment wall of red mud waste reservoir (Cassette No. 10) burst on 4 October 2010 during the daytime in Hungary. The catastrophe occurred near Ajka in the Central Transdanubian Region, about 50 km from Lake Balaton and 130 km from Budapest. About one million cubic metre of red mud sludge spilled and covered a territory of about 1,017 hectares. The caustic sludge flooded three villages (Kolontár, Devecser, Somlóvásárhely) and contaminated the rivers and streams including the nearest, the Torna, which flows into the Marcal and Raba rivers into the Danube (Figure 1).

During this tragedy, nine persons died, dozens of people were injured, mainly suffering from burns after coming into skin contact with the alkaline sludge, and 300 houses were flooded by the red mud sludge. Red mud sludge exhibits strongly alkaline properties, therefore, this environmental disaster resulted in an extremely serious situation.

Figure 1: The cathastrophe site near Ajka, Hungary, and the area contamintated by red sluge surface water from the Danube [4].

ENVIRONMENTAL MEASURES AND MONITORING

Immediately after the catastrophe, the University of Pannonia set up an emergency response team to carry out environmental monitoring and impact assessment, as well as to devise red mud sludge clean-up technologies. Experts took water, air and soil samples and established monitoring activities. Toxicity, pH, dissolved oxygen content, conductivity and surface water monitoring were carried out. The heavy metal content of soil samples taken from the critical points was also investigated. Air monitoring included particulate matter concentration, wind direction, air pressure and temperature measurements.

After the occurrence of the disaster, it was obvious that saving human lives is of vital importance and this was followed by the protection of the surface waters. It meant that the neutralisation of the caustic sodium hydroxide (pH = 12.5-13.0) had to be accomplished. Since there is no such thing as an environmentally friendly neutralisation agent from the environmental point of view, a novel solution had to be devised.

The conventional neutralisation of the sodium-hydroxide with acids (e.g. hydrochloric acid) could not have been allowed, and other less drastic acids (citric acid, acetic acid, maleic acid) were not available in large quantities. It was concluded that a salt of a strong acid and a weak base had to be used. Other theoretical solutions e.g. use of peat with an acidic character or sea water were not real options.

Since gypsum was available in significant quantities from coal-fired power plants as a waste material exhibiting a slightly acidic character, the use of gypsum was recommended to the Emergency Response Team, to be used at several points along the Torna stream, and the Marcal and Rába rivers. In addition to the gypsum, acetic acid was also used in controlled quantities at certain locations for the neutralisation.

Due to the extraordinary catastrophe, the Central Transdanubian Inspectorate for Environmental Protection, Nature Conversation and Water Management ordered water quality preparedness (3rd level) that included disinfection, averting and neutralisation the polluted surface water.

The decrease in pH value of the surface waters from 13 to 8 was achieved by gypsum addition into the Torna, Marcal and Raba, which was started within six or seven hours after the accident. Gypsum originating from the neutralisation of stack gases of a coal-fired power plant was added under controlled conditions and under continuous monitoring at several points along the streams and rivers.

In addition, acetic acid was added to the extremely contaminated water to adjust the pH level of the surface water. During the neutralisation action, 17,000 tonnes of gypsum and 4 m^3 of acetic acid were used up. Barriers were erected in the riverbed to slow down the flow of the Torna to provide sufficient time for neutralisation and settling of the residues. The primary objective, the protection of the Danube was successful as a consequence of the gypsum addition [4][5].

INCORPORATION OF THE DISASTER INTO THE ENVIRONMENTAL ENGINEERING CURRICULUM

The University of Pannonia offers BSc and MSc programmes in the field of environmental engineering. The Ajka red mud disaster case has been incorporated into the course programme on environmental impact assessment. The technology of bauxite processing and red mud storage technologies are explained to students and the emergency measures taken are given with practical insight into the monitoring and follow up actions. The efficiency of the emergency measures are assessed with the students and on-site monitoring is provided.

Students are taken to the site of the catastrophe and provided with an opportunity to carry out on-site measurements at different sampling points. Finally, the students are requested to devise remediation technologies and the outcome of their work is assessed by the group.

Moreover, students of the environmental engineering programme worked voluntarily after the disaster with the emergency team, after being granted a special permit to work at the contaminated sites, and provided help in cleanup and rehabilitation operations (Figure 2a).

They carried out surface water monitoring and soil sampling (Figure 2b) after the catastrophe, as well as monitoring and processing data on surface water quality parameters for several months after the accident. The data obtained have already been utilised in case studies, diploma work and in papers presented at conferences [6][7].

a) b)

Figure 2: Students at the catastrophe site: a) taking part in cleanup and rehabilitation actions; b) taking soil samples at the residual area of the village of Kolontár.

CONCLUSIONS

The bursting of the wall of the red mud storage facility near Ajka focused the attention of state agencies and the public on that technical and engineering inspections should be reconsidered in order to prevent future disasters.

It is recommended that emergency preparedness and procedures, the emergency response system, as well as the cleanup technologies should be checked continuously and updated regularly by national environmental authorities, especially in companies dealing with hazardous materials and technologies. Work on the reconstruction of the red mud sludge-containing waste disposal facilities has commenced.

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REFERENCES

1. Bánvölgyi, Gy. and Minh Huan, T., De-watering, disposal and utilization of red mud: state of the art and emerging technologies (2010), http://www.redmud.org/Files/banvolgyi040110.pdf
2. Hungarian Governmental Decree 101/1996 (VII.12) on the Promulgation of the Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. Signed in Basel on 22 March 1989, and its amendment 240/2005 (X. 27).

3. Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was adopted on 22 March 1989, http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx
4. EU experts to tackle Hungary toxic sludge, BBC news Europe, 11 October 2010, http://www.bbc.co.uk/news/world-europe-11512199
5. Hungarian Standard MSZ 12749:1993 on the of surface water, qualitative characteristics and qualification (1993), http://www.zoldinfolanc.hu/doksik/miskolc/vizek/Vizek2.htm
6. Piskor, B., Torna-patak Vízminőségének Megfigyelése On-line Mérőrednszerrel (On-line Monitoring System of Stream Torna Water Quality). A Case Study, Institute of Environmental Engineering, Engineering Faculty, University of Pannonia, February (2011).
7. Barabás, N. and Kovács, Zs., Application of a complex accredited water quality telemetry system for monitoring of water quality in Stream Torna. *Proc. Inter. Conf. on Emergency Management Technol*., Budapest-Veszprém-Szekszárd, 23-25 May (2011).