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Radioactive Waste Management Committee

Preservation of Records, Knowledge and Memory across Generations (RK&M)

Loss of information, records, knowledge and memory - Key factors in the history of conventional waste disposal

The RK&M project is seeking, among other things, to gain insights into the factors influencing the loss and recovery of knowledge and memory preservation in areas other than nuclear wastes. One area with similar characteristics, and therefore well-suited for comparisons, is that of landfills and old industrial or disposal sites for hazardous wastes. This report presents the results of an analysis of selected case studies of landfills and contaminated sites in Europe and other industrialized nations.

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PRESERVATION OF RECORDS, KNOWLEDGE AND MEMORY (RK&M) ACROSS GENERATIONS

LOSS OF INFORMATION, RECORDS, KNOWLEDGE AND MEMORY – KEY FACTORS IN THE HISTORY OF CONVENTIONAL WASTE DISPOSAL

FINAL REPORT
MARCH 2014

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FOREWORD

The NEA/RWMC project on the 'Preservation of Records, Knowledge and Memory across Generations' (RK&M) has launched a study to investigate the key factors for loss of records, knowledge and memory over time. The project aims to support the national programmes for radioactive waste disposal by developing guidance on regulatory, policy, managerial, and technical aspects of long-term preservation of relevant information.

Following a project workshop held in April 2012, the Institut für nachhaltige Abfallwirtschaft Zürich was commissioned to undertake an exploratory investigation into the loss of memory, caused by the loss of information, records and knowledge, relating to conventional landfills and contaminated sites of the past.

ACKNOWLEDGEMENTS

This study's main author was Marcos Buser (Institut für nachhaltige Abfallwirtschaft Zürich), on contract to the NEA. The document was further developed by the RK&M project team, especially by project members Sofie Tunbrant and Simon Wisbey, and by NEA staff.

1 INTRODUCTION

The RK&M project was launched in 2010, and is seeking, among other things, to gain insights into the factors influencing the loss and recovery of knowledge and memory preservation in areas other than nuclear wastes. One area with similar characteristics, and therefore well-suited for comparisons, is that of landfills and old industrial or disposal sites for hazardous wastes. This report presents the results of an analysis of selected case studies of landfills and contaminated sites in Europe and other industrialized nations.

Based on a two-part methodology (chapter 2), the study identifies common key factors relating to the loss of information, records, knowledge and memory (chapter 3) and defines criteria for the selection of cases to be examined in depth (chapter 4), as the number of landfills and disposal sites created during the last 100 years is high. Using these criteria, 21 cases of conventional, non-nuclear waste disposal from Switzerland, Germany and the United States have been selected. They are analysed in the final chapter of the study

2 METHOD

There is little historical experience of dealing with waste legacies and groundwater pollution from landfills. During the period of industrialization in the 18th century, especially with the advent of new technologies, both the energy consumption and the waste generated by the production and use of goods, increased sharply. This development is especially characteristic for the industrialized nations of the 20th century and continues today, in a slightly altered context, in the emerging developing countries.

The number of landfills and disposal sites created during the last 100 years is virtually innumerable, and the possibilities of investigating the loss of knowledge, accordingly vast. It was therefore necessary to narrow down the issue so that relevant processes with regards to information, knowledge and memory loss can be identified.

We therefore developed a two-part methodology for our data gathering and analysis. First, we identified the key factors that are considered important with respect to the loss of knowledge (see Chapter 3). These factors are similar to those chosen for a study on the marking of repositories for radioactive waste (Buser 2013), although the list of key factors was refined and expanded in the course of the investigation. Secondly, we established the criteria to select from the full set of landfill and disposal cases those cases that are representative of the phenomena of knowledge loss (see Chapter 4).

In the course of this study more than 20 selected cases have been considered. A list of potential interview-partners was prepared, all of them having long-term experience and deep insight in waste disposal and clean-up practices relating to dumps and contaminated areas. Some of these experts and officials were interviewed by the author.

We are aware that this simplistic methodology may not reveal all facets of knowledge losses. However, it should allow us to draw key conclusions and identify particularly relevant points to be considered, which may also have important applications for nuclear waste disposal.

3 KEY FACTORS RELATING TO THE LOSS OF INFORMATION, RECORDS, KNOWLEDGE AND MEMORY OF LANDFILLS AND CONTAMINATED SITES

The loss of knowledge and memory on former landfills and disposal sites may be due to different causes. Key factors for the loss of knowledge are compiled in Table 3-1.

No.	Key factor for loss of records and knowledge
1	Technical / environmental factors
1.1	Site degradation (including original technological installations)
1.2	Re-cultivation of old disposal sites / camouflage
1.3	No records / poor archives
1.4	No / insufficient update of records (e.g. maps, plans)
1.5	Loss /destruction of archives
2	Economic factors
2.1	No / insufficient budgets to fulfill the duties
3	Human factors
3.1	Personnel changes
3.2	General dis-interest in the area of RKM preservation
3.3	Negligence in the accomplishment of duties
3.4	Ignorance and/or incompetence
3.5	Arrogance
3.6	Underestimation of effective risks
3.7	Misunderstanding of information and records
3.8	Illegal activities (e.g. falsification of documents, unauthorized disposal)
3.9	Deliberate restraint / manipulation of data, information and records
4.	Structural factors
4.1	Discontinuities (e.g. war, social crisis, bankruptcy)
4.2	Structural deficiencies (e.g. lack of structural competence)
4.3	No / poor structural continuity
5	Regulation / laws
5.1	Lack of regulation / laws
6	Coupled processes
6.1	Any of the above in combination (e.g. ignorance and economics)

Table 3-1: Key factors contributing to loss of knowledge

A brief comment on each of them is given in the following paragraphs:

Technical / environmental factors

- Site degradation (including the technological installations): Knowledge can be lost if the upkeep of the site or the maintenance of important site installations is neglected or lost and/or the grounds are no longer recognizable as a deposal site.
- Re-cultivation of old disposal sites / camouflage: A further source of knowledge loss on landfills can be reclamation measures, following regulations by authorities when refilling gravel and clay pits or quarries.
- No records or poor archives: The lack of records and archives must be considered as a key source for the loss of knowledge.
- No or insufficient update of records (e.g. maps, plans): A particular characteristic of the loss of knowledge and memory can be failing to up-date plans or maps of the site (or the existence of plans, maps and records from different operating stages, which cannot be assigned unequivocally). The loss of knowledge and memory due to the implementation of new techniques to generate records, such as the transition from the classic reports on paper to electronic data, belongs in the same category.
- Loss /destruction of archives: The destruction or loss of important archive material is a key issue in the management of knowledge on landfills and waste deposits. Indeed, the fact that contaminated land registers have had to be re-created at high cost in many countries, illustrates the importance of this phenomenon.

Economic factors

No or insufficient budget to fulfill the duties: A classic and major source for the loss of knowledge that has to be considered is insufficient funds for their preservation.

Human factors

- Loss of knowledge and memory due to personnel changes: This is a particularly important source of loss, if the knowledge is not preserved or transferred before staff leave their post (e.g. retirement, change of job).
- General dis-interest: This is a major source of loss caused by a prevailing culture that the preservation of knowledge is generally looked upon as of little value. In such cases, a large if not essential part of the information and records can be lost.
- Negligence in the accomplishment of duties: This factor is closely related to the above-mentioned factor “general dis-interest”. It is often a consequence of a lack of interest.
- Ignorance and/or incompetence: Ignorance and incompetence are also expression of a lack of interest on the subject and an underestimation of the risks and hazards posed by waste deposits.
- Arrogance: Arrogance should be considered as source of loss of knowledge. The denial of warnings can play a significant role.
- Underestimation of effective risks: This factor is closely related to the training of competent staff. Many projects deliberately underestimate real risks arising from man-made and environmental hazards (chemicals, reactivity and degradation etc.).

- Misunderstanding of information / records: Carelessness, overtaxing or stress are contribute to this factor, all of which can lead to the loss of important knowledge.
- Illegal activities (e.g. falsification of documents, unauthorised disposal): This category of cases includes illegal acts that purposefully destroy or disguise records. There are some well-documented cases of deliberate knowledge destruction.
- Deliberate restraint / Manipulation of Data: Another important category of knowledge loss can result from the deliberate camouflage, falsification or manipulation of data, information and records. This often occurs at the interface between confidential programs and the public demand for information, and is especially relevant for contaminated sites in the military sector, for which information and records may have been deliberately withheld and in some cases may have been deliberately destroyed.

Structural factors

- Social discontinuities (e.g. war, social crisis): This factor refer to the knowledge loss during crises, both in terms of single companies (e.g. bankruptcy) as well as larger societal crises (economic depression, war).
- Structural deficiencies (e.g. lack of structural competence): This factor is typically strongly underestimated or often not even recognized as a relevant factor. If public or private structures are not designed to collect, classify and store the appropriate records, then the loss of knowledge is bound to occur. The loss of knowledge may also be only partial, e.g. when irrelevant data is collected.
- No or poor structural continuity: Structural changes (e.g. reorganizations, restructuring of duties in administrations and companies) or technological innovation (e.g. introduction of new writing tools (typewriter / computer) is another important reason for the loss of knowledge.

Regulation / laws

- Lack of regulation / laws: It is also important to note that many of the above reasons for the loss of information, records and knowledge simply result of the fact that the regulator has not enacted legal regulations, or at least not enacted binding regulations, with regards to how to deal with records.

Coupled processes (e.g. ignorance and economics)

Clearly, coupled processes can play an important role as well, as is most easily shown in instances of crisis and lack of resources. The study will now compare the various factors against actual examples of contaminated sites and landfills and organize them clearly. For this purpose, a number of landfills and contaminated sites will be investigated in greater detail.

4 SELECTION CRITERIA FOR THE INVESTIGATION OF SPECIFIC CASES OF KNOWLEDGE LOSS

The number of contaminated sites, landfills and facilities with materials hazardous to the environment is very large. Each example has its unique history and the identification of common causes within this large number of cases has limits. Nevertheless, the loss of knowledge, through the loss of information and records, often has similar underlying reasons that can reasonably be categorized.

The level of risk posed by a particular facility may be a strong influence on the preservation of information, records and knowledge. Small, simple landfills with inert materials and harmless waste may fall into oblivion more quickly than landfills and dumps containing dangerous and long-lived waste.

In Switzerland, there are about 50,000 known sites containing pollutants arising from landfills, facilities or accidents. About 4,000 of them are considered contaminated sites (BAFU and BfS 2011), of which only a very small part is regarded as in need for environmental remediation/clean-up. The majority of the contaminated sites are considered as requiring special supervision (ibid.).

In Germany, more precise information is available on the number of old landfills and contaminated sites, as well as on the status of the environmental remediation. However, it should be noted here that the environmental remediation cannot always be understood as the removal of the contents of a pit, but is often understood only as an encapsulating or covering of a landfill site. Table 4-1 provides information on the number of old sites and the environmental remediation measures that are currently underway.

Region	Status (date)	"Suspect areas"	Old deposits	Disposal sites	Hazardous sites	Clean-up achieved	Risk asst. achieved	Clean-up in progress	Monitored
Baden-Württem.	12/2010	13'840	1'722	12'118	2'219	2'624	15'228	620	435
Bayern	03/2011	16'795	11'495	5'300	1'051	1'658	5'088	966	85
Berlin	07/2011	5'240	1'166	4'719	937	191	no info	71	72
Brandenburg	07/2011	19'738	7'083	12'655	1'476	4'073	4'279	131	234
Bremen	06/2011	3'557	32	3'525	408	621	951	42	167
Hamburg	01/2011	1'815	271	1'557	533	426	3'093	147	140
Hessen	07/2011	1'040	545	495	436	880	1'922	236	51
Mecklenburg-V.	12/2010	5'835	2'648	3'187	999	1'155	267	359	396
Niedersachsen	06/2011	93'825	9'546	84'279	3'482	1'597	4'714	381	535
Nordrhein-West.	01/2010	75'370	30'493	44'877	no info	6'158	17'969	no info	no info
Rheinland-Pfalz	07/2011	12'497	11'929	568	296	128	6'516	168	58
Saarland	05/2010	1'977	1'650	323	456	156	379	35	64
Sachsen	05/2011	19'785	6'783	13'002	627	2'927	6'638	434	1'474
Sachsen-Anhalt	05/2011	16'682	5'103	11'579	186	1'680	3'662	71	50
Schleswig-Hols.	12/2010	13'781	2'191	11'590	320	974	2'472	66	54
Thüringen	03/2011	12'570	3'924	8'646	783	837	4'506	191	71

Table 4-1: Waste disposal areas according to the German ministry of environment

Notes for Table 4-1:

Data from 'National overview of the waste disposal sites statistics in Germany (status 7/2011), www.umweltbundesamt.de/boden-und-altlasten/altlast/.../1_3.htm

Old deposits (Former deposits / Altablagerungen AA after § 2 paragraph 5, nr. 1 of the german law of soil protection, march 17th 1998 (Bundes-Bodenschutzgesetzes);

Disposal sites (Altstandorte AS after § 2 paragraph 5, nr. 2 of the german law of soil protection, march 17th 1998 (Bundes-Bodenschutzgesetzes);

Hazardous sites (Altlasten after § 2 paragraph 5, of the german law of soil protection, march 17th 1998 (Bundes-Bodenschutzgesetzes);

Clean-up achieved (Sanierung abgeschlossen);

Risk assessment achieved (Gefährdungsabschätzung abgeschlosssen);

Clean-up of hazardous sites in progress (Altlasten in der Sanierung);

Monitoring (Überwachungen)

Those sites in which there is a suspicion of harmful soil changes or other dangers to the individual or the public are labelled "**Suspect areas**"- (altlastverdächtige Flächen). There are currently more than 271,000 sites in Germany, which are recognized as "Suspect areas". Details on the latest figures and on the number of areas covered can be found here.

After the reunification, the territory of the former GDR had numerous contaminated sites that needed to be registered and remediated. An example, until now unknown, for the extent of a contaminated site is the region around Bitterfeld, see WBGU (1994).

This study does not allow for a truly broad-based analysis of case studies. However, by means of a careful selection of specific case studies, mechanisms for the loss of information, records and knowledge can be analyzed and documented. Since sufficient study material is available, the selection of case studies was driven mainly by the following considerations:

- Integration of the preliminary results of the study that was presented by SKB staff at the RK&M workshop in October 2011.
- Surveys of public authorities or private companies on information, records and knowledge loss concerning landfills and old waste deposits in parts of the country (canton Zurich, Canton Aargau), where sufficient reliable data is available.
- Personal experience in the environmental remediation of old landfills or large disposal sites.
- Literature study on known contaminated sites and search for specific patterns of information, records and knowledge loss.

On this basis a representative number of examples, selected to highlight the problems of memory loss, were analysed and are briefly described in Section 5. It was important for this study to characterize the nature of the information, records and knowledge that was lost and to identify its relevance to the subsequent management of the site.

5 SPECIFIC CASES OF LOSS OF INFORMATION, RECORDS, KNOWLEDGE AND MEMORY RELATING TO CONVENTIONAL WASTE DISPOSAL

Despite the many differences between the countries of the world, the day to day practice of dealing with waste shows striking similarities. In general terms, the industrialization cycles in modern economies follow the same patterns. At the beginning of an industrial process, waste disposal costs nothing or almost nothing, and the personal and financial resources needed for establishing and maintaining information and records are largely absent. We can observe throughout the world a very similar handling of waste in different stages of economic development, in which cultural differences between nations or time plays only a minor role.

Waste disposal activities are not held in high regard, therefore, our societies do not particularly care about the issue. They do just as much as necessary. Waste disposal policy is viewed as something unpleasant, something that we prefer not to speak about. Under these conditions it is not surprising that it is difficult to get reliable information. Valuable information very often only comes from those directly involved in the waste disposal system. They know the weaknesses and vulnerabilities of such systems, even if they do not particularly like talking about it.

Many of the following examples were obtained from personal experience or from experts and authorities that are very familiar with disposal practices. Other information came from cases that had been particularly well studied, and from published proceedings of court cases. The author is very grateful to all the experts and officers who provided inputs, for the openness. They provided vital insights into an unpleasant reality.

In the following chapters several cases are described, showing how loss of information, records, knowledge and memory can occur. Many of these examples come from highly industrialized countries such as Switzerland and Germany and show how information about landfills and industrial sites was lost within a single generation. This is also demonstrated by the attempts of the government to acquire information about the deposited waste in hindsight.

5.1 Loss of information, records, knowledge and memory in Switzerland

5.1.1 Fabrique de Chaux SA, St-Ursanne, Jura, 1907–2007

Findings: Between 1907 and 1993 the Fabrique de Chaux in the Jura mountains near Delémont (Canton of Jura) produced fired chalk from reef limestone with very high carbonate content. The reef limestone was extracted from an underground mine, located directly above a local aquifer and below two rivers that, until 2005, accommodated various pools with fish farms. Hydrogeological studies showed that coloured tracers injected in the mine reached the rivers and pools within a few hours.

The Fabrique de Chaux backfilled several major galleries in the old mine with their industrial waste (Figure 5.1-1). Among the different sorts of wastes were also barrels containing heavy oil from the operation of the lime kiln.

Due to a lack of economic prospects Fabrique de Chaux stopped operation in 1993 and sold the facilities to a waste management company. This company was planning to consolidate hazardous waste with a cement mixture and accumulated large quantities of unconsolidated waste into the galleries (Figure 5.1-1). The company's activities were discovered when Greenpeace activists occupied the site in 1994.

Because the state authorities did not act, Greenpeace occupied the site for a second time in 1995. As a result, authorities and experts investigated the case and exposed the unauthorised activities. The waste company was declared bankrupt in March 1997. The canton of Jura needed to dispose of the temporary stored hazardous waste at its own expense. The former employees of the company did not reveal any information about the case.

The bankruptcy office in charge opened the archives, and the cantonal environment agency was brought in to assess the documents. It rated the technical documents of the factory as insufficiently valuable to warrant further archiving. All technical reports were thus destroyed. In consequence, valuable knowledge about the infrastructure of the factory was lost, and needed, so far as possible, to be restored at great expense.

Figure 5.1-1: Some pictures of the waste inventory inside the galleries of the chalk mine of St-Ursanne, archive of the DMS-project of the Canton of Jura (on the left are some of the thousands empty or filled drums dumped into the mine between 1970 and 1993, and on the right: big-bags with galvanic waste emplaced in 1995)

Knowledge about the disposal of the heavy oil barrels of the Fabrique de Chaux was already lost in 1997. Although the responsible office was directly adjacent to the former mine, no-one could provide information on possible waste disposal practices inside the galleries. Many former workers had moved away or died already. Explorations with excavators and investigations by a specialized staff of speleologists inside the galleries reported the existence of water-polluting liquids. The great hazard posed to rivers and groundwater by the oil residues led to the complete investigation of the filled galleries. The entire mine has now been studied systematically and all wastes were recovered in an operation that concluded in 2007, at the expense of the state.

Comments: The case of the Fabrique de Chaux is very typical of the situation in the late nineties in Switzerland. Until 1998 no legal provisions for the remediation of contaminated sites existed, and there was no legal obligation to intervene on the part of the authorities. A number of different factors relating to the loss of information, records and knowledge can be identified from this example.

First of all, much information and a lot of knowledge about former disposal activities in the mine was lost because the awareness of the potential environmental damage was simply lacking. A former miner later testified that he was shocked to see that he himself had taken part in the emplacement of the operational waste of Fabrique de Chaux into the galleries. Secondly, at that time hardly anyone was interested in waste. The new operating company, which acquired the site in 1993 as underground storage facility for solid waste (hazardous waste), did not care about the waste that has been emplaced earlier. Once the waste management company had taken over the site, the situation became more complex because information had been deliberately concealed. In the final phase of the case, potentially illegal activities of the waste company, including destruction of information and records, are clearly detectable. Finally, after the

bankruptcy of the company, archives were lost because the responsible authorities misjudged the value of the records. All of these reasons can be attributed to human deficiencies.

By analysis of the case of Fabrique de Chaux, almost all of the factors for loss of information, records and knowledge that were presented in Chapter 3 can be identified. This is a major insight that can probably be applied to most old landfills.

5.1.2 Céramiques industrielles SA (CISA), Bonfol, Jura, 1995–1997

Findings: A similar situation appeared in the case of Céramiques Industrielles de Bonfol SA (CISA), which operated a large clay pit for more than two decades. In the early 1960s, in order to comply with the requirements and obligations of the clean-up of the pit, CISA sold the rights to a company of the Basel Chemical Industry. This company then converted the clay pit, via several stages, into a hazardous waste landfill (see section 5.1.3). In 1975, the hazardous waste landfill was closed. Starting in 2000, the Basel Chemical Industry committed itself to clean up their old hazardous waste site completely. In 2000, CISA was declared bankrupt. As in the case of the Fabrique de Chaux, the technical and geological reports, including plans of the old pit, were completely destroyed. In fact the entire archive was disposed of in the nearest landfill, and as a result, valuable knowledge which would have been of great value for the clean-up of the waste site was lost.

Comments: Although clean-up was already planned or in progress, the communication between the relevant administrative bodies failed. The importance of the technical and geological records for the clean-up was not recognized neither by the authorities nor by the chemical industry in charge of the clean-up. The history of the clay pit had, as far as possible, to be reconstructed at great expense.

Inter-disciplinary communication has to be ensured when dealing with complex problems. It is not enough for government agencies to carry out their statutory duties. It is also necessary that the transfer of information and records is not left to chance, but that it takes place according to clearly defined rules.

5.1.3 Décharge Industrielle de Bonfol DIB, Bonfol, Jura,

Findings: The Bonfol landfill of the Basel Chemical Industry is one of the major hazardous waste sites in Switzerland. It was set in a clay pit that was mined (mostly during and after the Second World War). The entire inventory of chemical, agrochemical and pharmaceutical waste produced by seven companies between 1961 and 1975 found their way into the landfill. Some aspects of the site's history are of great interest to the RK&M project. First, the operator of the landfill, the company Geigy AG (from 1970 after mergers: Ciba-Geigy AG), did not operate a proper waste disposal cadastre (register of ownership and tenure). Indeed, the transportation bills for the majority of the 200l steel drums delivered to the site containing chemical wastes embodies very little usable information.

Although the authorities later asked the Basel chemical industry to create production lists and thus waste lists from that time period, they only received evasive answers from the operators. It is unclear whether the knowledge of the stored waste had actually been lost or whether information is retained in view of the hazardous nature of the stored materials. In any case, a lot of knowledge concerning the content and condition of the landfill was lost due to the chaotic filling process and the extensive corrosion of the drums (see Figure 5.1-3).

Figure 5.1-3: Some pictures of the waste dump for chemical wastes deposited between 1961 and 1975 in a clay pit near the village of Bonfol, Jura, Switzerland

On 7 July 2010, during excavation near the edges of the waste disposal site, an explosion occurred. Fortunately it caused no human injury but it stopped the clean-up-operation for over 1 year. The explosion was attributed to chlorates, which had been ignited by a spark from the excavator shovel. This event highlights two aspects: First, this incident confirms the limited knowledge about the disposed wastes and their subsequent chemical reactions. Secondly, it also documents the gaps in knowledge regarding the geometry of the landfill, which, despite later studies during the historical site assessment (e.g. evaluation of aerial shots), could not be detected with the required accuracy.

Comments: The example of the Bonfol waste disposal site is particularly intresting for the RK&M project. As with all early landfills, knowledge of the waste and the condition of the landfill is very limited. The records of the past, if they exist at all, are incomplete. Even by means of historical research the only a limited extent of the knowledge is recoverable.

The example of the hazardous waste disposal site Bonfol also illustrates another phenomenon very nicely. The loss of knowledge on landfill content and the resulting risks to the environment are not solely attributable to the lack of awareness. Equally important is the question of control over the knowledge. In many countries of the industrialized world, the 'Polluter Pays' principle has been established as a guideline for the handling of waste and contaminated sites. It places the polluter under the obligation to pay for proper disposal, or for damages resulting from a deficient practice of the past. Associated with the polluter pays principle is the need to manage data and knowledge, and this is solely under the responsibility of the operator.

As the example of the Bonfol hazardous waste landfill illustrates, the polluter has a very wide margin of discretion in how he wants to deal with his knowledge and data. To this date, the extent of knowledge on the waste legacy remains unclear due to a lack of disclosure of the archives by the Basler Chemie (see Section 5.1.4). Since compensation claims on the part of aggrieved landowners in the neighborhood may yet arise, it can be assumed that the operators of such facilities tend to restrict access to the information, and the waste owners have no fundamental interest to disclose the extent of past bad decisions and potentially illegal practices.

5.1.4 Landfills of the Chemical Industry around Basel

Findings: The story of the chemical industry landfills in the Basel area that were successively engineered since the Second World War has been worked up in very comprehensive and detailed investigations (Forter 2000, Forter 2010). The wastes of the Basel chemical industry were passed directly into the Rhine or dumped in the middle of the river by a ferryboat until the 1960s. Due to the protests from the population, the Basel chemical industry began disposing of their waste in landfills in the vicinity of

Basel, partly also on German and French territory near the border (Grenzach FRG, Le Letten Hagenthal le Bas F, Roemisloch-Neuwiller F, Feldreben Muttenz CH etc., see Figure 5.1-4). Although protests were heard in some communities because of recurring pollution, the Basel chemical industry responded evasively for decades. The affected communities did not have enough weight to prevail against the powerful companies of the Basel chemical industry. The cleanup of the old sites got under way only gradually in recent years, after environmental groups and experts began to step in.

Figure 5.1-4: Some pictures on waste handling of the Basel Chemical Industry. To the left: discharge in the Rhine (1965); in the middle: the Feldreben-dump in an old gravel pit in Muttenz near Basel (1955); to the right: the dump of Roemisloch in Neuwiller, Alsace (2011)

As with other dumps, there was little information and knowledge on content, the quantity and toxicity of the disposed waste, the extent of the landfill and the impact on the environment. For decades there was no proper monitoring of the various places of disposal, and the archives of the Basel chemical industry remained largely inaccessible. The archives of the city of Basel and the Swiss, German and French authorities give only sporadic information about special events. Martin Forter lists the archival sources in detail in his book "Farbenspiel" [3]. The majority are letters between the agencies, affected communities and industry, protocols of meetings of municipal councils, and decrees of authorities in case of infringement. Occasionally it also concerns inspection results and rarely site assessments, even reports from the press. Syntheses on the knowledge of each landfill sites were, as far as ascertainable, not ordered by the responsible entities, or at best demanded within the redevelopment projects.

Comments: The history of the landfills of the Basel chemical industry are of great interest for the RK&M project. With these examples, the resistance of the polluter towards taking responsibility for their waste, documentation of specific acts and the cleanup of pollution become evident. Once again economic considerations (waste should cost nothing), and later legal considerations for annulment or concerns about maintenance costs and loss of reputation are at the forefront of actions. The level of information remains meager despite great efforts in the course of the clean up projects. Essential information about the content and quantity of the waste disposed of is missing and can only be restored to a limited extent and at enormous expense.

These studies confirm the lax handling of waste and the general disinterest of the chemical industry with regards to documentation and archives, as long as the waste could be disposed of at the lowest possible cost. But the examples also show very clearly that the industry had a more or less free hand in informing the authorities and the public. As long as no public pressure was present, the aftercare of the landfill was only minimal. Only the public pressure in the wake of the rising environmental awareness prompted the chemical industry to take measures for their long-term management. But the information about the actual state of the contamination and the extent of damage to the environment were, if at all, disclosed very cautiously. The very late legal regulation in the field of contaminated sites, the law adopted in the United States (Comprehensive Environmental Response, Compensation, and Liability Act

[CERCLA] in 1986) was followed by legislation in Europe only in 1998[1], supported the defensive attitude of the polluter.

5.1.5 Riet landfill site, city of Winterthur

Findings: The Riet landfill is the big disposal site for domestic and industrial waste of the city of Winterthur. It was operated since the beginning of the 20th century and was, as far as the old parts of the landfill are concerned, built on an ancient system of drainage ditches and drains, which were part of a large agricultural improvement scheme (melioration), mostly built between the First and Second World Wars. The landfill was operated until the 1970s without any further protective measures. One of these ditches was used as central waste water drainage of the landfill. This way, the landfill leakage found its way directly into the groundwater and a stream.

After groundwater contamination had occurred, the responsible authorities decided to clean up the waste site. The exploration work and the redevelopment plan also included historical studies. In the course of this work the old agricultural melioration plans were rediscovered, and the importance of the old drains for the drainage of the landfill was realized. In this way, commonly known information and knowledge gaps can also be identified in the case of the Riet landfill: lack of waste cadastres, generally poor information, neglecting of archives, lack of synthesis, lack of resources for the long-term documentation, etc. The documentation and archive services of environmental data are neglected, even in a rich country like Switzerland.

Comments: From today's perspective, the original operators would not have been aware of the danger of waste materials with regards to the groundwater. At the time (beginning of the 20th century), the city council had chosen a very remote area. The environmental pollution by the landfill was only recognized much later, when there was a shift in the perception of ecological values.

The case of Riet shows that concepts for final disposal and security considerations change in the course of time, and in consequence, fundamentally new questions about long-term safety validation arise. It is also seen from this example how important inter-disciplinary contacts are. For decades, it did not cross the minds of the investigating geologist to consult with the drainage plans of the cantonal melioration office.

[1]See, for instance, the German "Gesetz zum Schutz vor schädlichen Bodenveränderungen und zur Sanierung von Altlasten (BBodSChG) vom 17. März 1998 in der BRD" and "Verordnung über die Sanierung von belasteten Standorten (Altlastenverordnung) vom 26. August 1998" (both in German).

5.1.6 Landfill site of Bärengraben, Würenlingen (Argovia)

Findings: The landfill of Bärengraben has been established by a consortium of public institutions (municipality of Würenlingen, Canton of Argovia and waste incineration plant of Turgi) in the 1960s in an old marl quarry of a major regional cement factory. Until its closure, up to 4 million cubic metres (m^3) of waste were deposited, mainly garbage, slags and construction wastes, but also including around 300'000 tons of industrial wastes.

The landfill was developed directly over the rock without protective measures and without sealing at the base, as originally proposed by a geological consultant. However, it seems that the base of the landfill has quickly been clogged by finer suspension fractions of the seepage. The weakest part of the geologic safety system of the landfill of Bärenfraben was the lack of a rock barrier in the area where leachate drainage was constructed, thus allowing leachates from the landfill to reach the groundwater of the lower Aare valley (shown by the big red arrow in Figure 5.1-6), thus seriously contaminating the groundwater and even threatening the water supply.

In order to collect samples of the leachate from the sloping part of the landfill, engineers firstly placed a drainage ring around the open landfill (see Figure 5.1-6 white ring in the middle of the landfill). The success of this measure was very limited, because a major karst source has not been taken into account. These natural karstic sources from the rock cliff were originally known during the exploration activity of the quarry, but information had been lost through time. In the 1990s, the Canton of Argovia had to realize a tunnel under the landfill with a water collection drainage system (see green tunnel in Figure 5.1-6) in order to collect more leachates originated by karstic inflow.

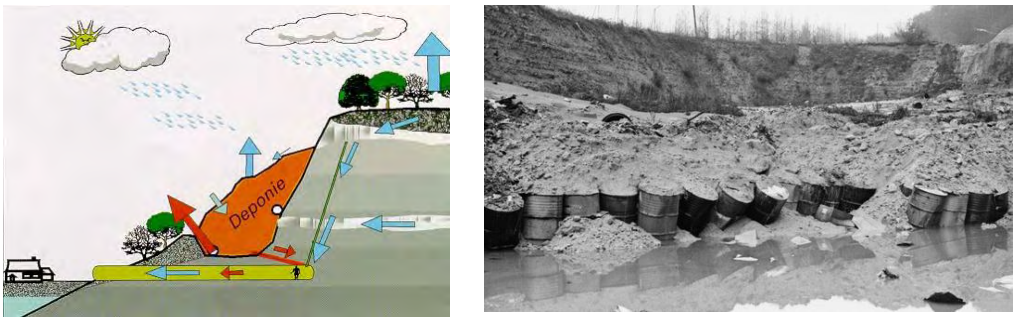

Figure 5.1-6: Bärengraben landfill, Würenlingen, Switzerland. Cross-section through the marl quarry of the Effinger member and water-cycle around the landfill, in green the leachate collecting drainage tunnel (left picture); Disposal activities 1974, disposal of industrial wastes in 200l-drums (right picture), information about the content has never been collected (Photo: Hans Lüthi, archive of Aargauer Zeitung[2])

The landfill of Bärengraben reached celebrity status at the end of the eighties, when it became public that the municipality recorder (Gemeindeschreiber) had permitted the disposal of very large quantities of chemical wastes from a German transporter (up to several ten thousands of tons), and had been paid for this illegal service. The responsible person was convicted in criminal court and condemned to several years

[2]Nicole Bächli (2011), "Bärengraben: Die grösste Aargauer Deponie macht dicht", Aargauer Zeitung, 9 August, 2011, last accessed 25 February, 2014, http://www.aargauerzeitung.ch/aargau/baden/baerengraben-die-groesste-aargauer-deponie-macht-dicht-111645355 (in German).

in prison. However, neither amounts nor content of the drums of industrial wastes could really be reconstructed, as the information was almost completely lost. Bärengraben is one of the rare cases, where criminal activities associated with illegal dumping of industrial wastes could be detected and proven.

Comments: The case of the Bärengraben is interesting in the context of the RK&M project for three reasons. First, the Bärengraben case shows that for a long time the disposal of hazardous waste has been implemented while being conscious that information about the nature and origin of the waste was being "lost". In effect, the waste producers passed their often sparsely labeled wastes on to disposers, which passed them on to a landfill. No records were kept on this disposal chain. In the end, usually only the transporter of the waste was known. What was stored where was of no interest to the waste producers, nor the authorities, nor the disposal firms. This way a lot of valuable information was lost. All responsible parties, whether legislators, executive institutions or companies, accepted the immediate loss of information as well as a potential damage to the environment. They operated on the principles of the zeitgeist (spirit of the age). As long as they were not questioned, there was no reason to question their own actions.

Secondly, the Bärengraben case also illustrates that once lost information can be very difficult to recover, if at all. Costly chemical analysis of the waste barrels could provide important information on the kind of disposed wastes. However, for this purpose these barrels would need to be retrieved, which would require at least a partial clean-up of the waste disposal sites, as is currently the case with the chemical waste landfill of Kölliken (AG). However, even the context, origin and producer, agreements, safety measures etc., can hardly be restored. The loss of information is too far reaching.

Finally, the Bärengraben case illustrates the deliberate concealment of information by criminal activity. Criminal activities in the waste sector are notoriously difficult to prove because there is often a lack of will, and thus a lack of resources to trace illegal activities. Nevertheless, criminal activity associated with an extensive if not complete loss of information and knowledge about the waste products may be common. A simple 'Google' search using terms: 'criminal activity waste disposal' shows a grand total of 40,000 entries![3] Hence, we are still far from being able to speak of a marginal phenomenon in the conventional waste sector.

5.1.7 Tössegg landfill site, Wildberg (Zürich)

Findings: The Tössegg landfill, in the municipality Wildenberg in Tösstal at Winterthur (Canton Zurich) won mainstream notoriety with regards to the Russikon oil refinery residues (Madetswil / Russikon, ZH). In the 1960s and 1970s, the refinery regenerated mineral oils, with residues made of acid tar, a mixture of viscous, tar-like products, sulfuric acid and liquid oil. The oils also contained high concentrations of polychlorinated biphenyls (PCB). These residues were bottled in 200l-drums. Between 1970 and 1974 around 8,000 such barrels were disposed of in 17 pits in the landfill of the municipality Tössegg Wildenberg (ZH) (see Figure 5.1-7). The refinery assumed that the waste oil residues would solidify like paraffin. In addition, the project managers assumed that the quaternary moraines, where the pits had been dug out, were leak proof and would provide sufficient protection from potential groundwater contamination of the important aquifers in the catchment area of the city of Winterthur. Both assumptions turned out to be false.

[3]See, for instance, Rob White (2012), Environmental Crime: A Reader, Portland: Willian Publishing, or, for an earlier example, Andrew Szasz (1986), "Corporations, Organized Crime, and the Disposal of Hazardous Waste: An Examination of the Making of a Criminogenic Regulatory Structure", Criminology, 24:1, pp. 1–27.

Figure 5.1-7: Landfill for acid resin of Tössegg, Wildberg, Switzerland. Location of the disposal 1 to 17 filled by more than 8'000 200l-drums with PCB-containing acid resins (according Geotechnisches Institut o.J., nach http://www.geo-online.com/portrait/referenzen.cfm)

First pollutions of groundwater beneath the landfill had already been detected in the 1980s. The first imposed clean-up work focused on the collection of the toxic seepage with drainage lines, initially near-surface drainage, later a second deeper drainage line. In 1989, the Canton of Zurich was still assuming that no further controls on groundwater or interventions in the landfill would be necessary and that the eluates from the landfill were within the law. However, recurring small tar seepages finally led to further investigations in 1994. The enlisted experts assessed different needs for clean-up measures, and the responsible cantonal environmental office decided to leave the matter alone and ordered no further measures. The cantonal authorities seem to have wanted actively to forget the case.

The case only got underway again because the mayor of the local municipality Wildberg did not give up, confronting the planning director of the Canton of Zurich in charge at the time, with regards to the problems of the landfill. Parliamentary inquiries in the cantonal council ensured further pressure. As a consequence, the authorities in charge initiated further investigations in 1998, which confirmed the danger of the landfill to the groundwater. As a result, the landfill had to be remediated. The acid-tar-landfill Tössegg was excavated and cleaned up in several stages at a cost of approximately fourteen million Swiss francs between 1998 and 2001.

Comments: This case is interesting because it shows that the desire for active forgetting came from the administration, thus the public authorities. The responsible department and the former planning director wanted to rest the case of the Tössegg landfill. Only political intervention of the local authorities and the cantonal parliament led to in-depth investigations, the re-evaluation of the risk situation and finally to the complete re-development of the landfill.

Many landfills are "managed" in the same way. As long as there is no urgent need for action, old deposits are left "resting". The national authorities only step in as a last resort for orphan or trans-generational legacy problems when specific problems arise. In most cases these problems relate to groundwater contamination or gas release, which is why these dumps are currently monitored "permanently" (see below) in rich countries such as Switzerland and Germany. Given the large amount of old waste deposits, the enormous follow-up cost of remediation, and the often questionable nature of restoration programs, any other strategy is currently doomed to fail. Therefore, authorities as well as experts are content with leaving the old deposits for natural attenuation and settle for occasional groundwater and in some cases soil inspections.

This strategy is also an expression of the limited financial resources, which the relevant government agencies have at their disposal for such follow-up programs. This tight financial constraint limits the funds that can be used for the preservation of knowledge on these sites or the updating and expansion of the knowledge, even in rich countries. In this sense the authorities are put in a role of guardianship. Active measures are taken only if significant contamination or environmental problems arise.

5.1.8 Hardwald landfill, Urdorf (Zürich) and Homberg landfill, Kloten (Zürich)

Findings: The Hardwald landfill, in the municipality of Urdorf, at the Winigen motorway junction, is one of the large old landfills in the area of the Canton of Zurich. Like many other landfills in gravel-and sand-rich river valleys, the Hardwald landfill originated as a result of gravel extraction in the Limmat valley and the requirements by the authorities to refill and re-vegetate the mining area. Hardwald took more or less the entire waste inventory including, among other things, commercial and industrial waste, from the whole of Zurich and its vicinity. The aforementioned Russikon refinery (see section 5.1.7) delivered much larger amounts of acid tar to Hardwald then to the Tössegg pits. The landfill gained popularity in the 1950s because hospitals and research centres, as well as the industry of Zurich, even disposed of their radioactive wastes in the landfill, where they were covered with a three-metre thick layer of clay.[4] Accurate inventory and waste disposal location in the landfill are unknown today. The cantonal register of old waste deposits does not list these radioactive sources.

During the construction of the motorway interchange in the 1980s, the Canton started to de-gas the landfill. However, the groundwater and gas monitoring program was discontinued after a few years due to the lack of finances and lack of information about major pollutants. The monitoring of the landfill was only resumed following a complaint from a company that operated a large concrete preparation and gravel area next to the landfill and got the attention of the authorities. The results of this monitoring program were again negative and so the authorities abandoned the monitoring for a second time. In the 1990s a building was erected on the edge of the Hardwald landfill. While digging the construction trench black liquids were found, but the authorities did not investigate the source of the pollution. The case was not pursued further as the authorities appeared to have a policy of deliberately wanting to forget. The Hardwald landfill was a great legacy of the region and the authorities wanted to let sleeping dogs lie. Even in the mid-1990s, during the implementation of the cadastre of polluted sites (Katasters belasteter Standorte KBS), no inventory was completed for the industrial and commercial waste in the landfill. As long as no acute environmental problems arose, the authorities in charge ordered no measures to extend the knowledge base. Today, the authorities are content with responding to cases of acute pollution. There are no funds for further measures, such as the systematic maintenance of information.

A similar situation can be found for the Homberg landfill, near the important groundwater resurgence of the "golden gate" ("goldenes Tor") in the vicinity of Zürich airport. The inventory of this landfill is more or less typical for urban regions: garbage and slags from incinerated domestic wastes, some wastes from industry and trade, building wastes, and so on. Even radioactive wastes were deposited until the federal government began to collect them in 1963. However, the responsible authorities did not order any special measures over and above the normal monitoring programs for groundwater and landfill gas. Officially, there is no need to protect the environment from such sites, but in reality the authorities appear to encourage active disregard of former disposal sites.

[4] Interpellation Bernhard Zwicker, Walter Schnyder und Ernts Diggelmann vom 20. November 1957 im Gemeinderat, Protokoll des Gemeinderats 1954-1958, Band II, S. 1698 (in German).

Comments: These two examples show another important component in the process of records loss. This happens not only due to human error, carelessness and lack of foresight, but the desire to forget can also be actively pursued. As a defence mechanism, repression and loss of memory are both known from many disciplines, such as psychology (Frankl), journalism (Pöttker et al.) as well as from history (Meier). In the field of waste disposal, active oblivion is practised to ward off unpleasant realities or to conceal errors that were made in the past. This finding is interesting because it not only applies to individual behavior, but also reflects the work of state institutions. The act of forgetting (i.e. of suppression) is therefore intended, is sanctioned by the state and thus systematic. While the zeitgeist shapes the values and consequential actions, the ability to exercise power is more important in this context. State agencies as well as economic institutions operate quite simply by using their power in order to keep the unpleasant at bay. This way, memory and oblivion can be controlled.

5.2 Loss of information, records, knowledge and memory in Germany

In addition to municipal and commercial waste, Germany is an interesting country in terms of industrial and military contaminated sites. First, it is a densely populated country, and was industrialized early. Key industries such as the chemical and pharmaceutical industry, the heavy and machine industry as well as furnaces and gas- or coal-fired power plants emerged in the 19th century and soon led Germany to the top of the world's industrialized nations. As elsewhere, the hazardous nature of wastes from industrial processes, at least in terms of their long-term risks, were significantly underestimated. The management of this waste was based on historic recycling practices, or the burial of waste right at the production sites or in the immediate vicinity.

On the other hand, Germany has had an extraordinarily turbulent history, with two World Wars that took partly place on German soil. Conflicts of this sort led to shifting national borders and extensive population migrations, the resettlement of entire industries, and to a prolonged occupation by the victorious nations. The turmoil of war with the associated migration waves led to large losses in archives and promoted the loss of memory relating to whole industries, including therefore the history of its wastes. Moreover, the occupying nations were not particularly sympathetic to the ecology of the occupied Territories, and may not have applied the same standards of environmental control in Germany as they would have at home.

The state of Baden-Württemberg is playing a pioneering role in the contaminated sites exploration in Germany. In 1988 the state published the first contaminated sites handbook of the Federal Republic, which contained detailed information, such as how old industrial sites and landfills can be investigated and how the lost knowledge on waste dumps could be (partially) rebuilt (MfUV 1988). The origin of this guide were the increasing number of identified soil and groundwater contamination sites, and the growing public awareness of environmental issues, especially since the 1970s. The following sections illustrate a number of examples on the handling of hazardous contaminated sites in Germany.

5.2.1 Kehl Gasworks

Findings: At the end of the 1980s the water management offices in Germany had to fill out registration forms for the recording of contaminated sites. They passed these forms on to the municipalities, which created a rough list of possible contaminated areas. However, the sites known from the first survey had to be examined meticulously, which was often difficult because many of the suspected sites had been fundamentally redesigned. This was the case in the former location of the gas works and the tar oil production facility, about 600 meters east of the Rhine in the city of Kehl. Soil and groundwater

beneath the site were contaminated with high concentrations of polycyclic aromatic hydrocarbons (PAHs), which could be detected in groundwater down to depths of about 20 metres (LfU 2001).

The gas works and tar oil production facility were originally located on a channel, the so called "Schuttermühlkanal" (see Figure 5.2-1). This channel was considered by the health authorities of the city as a source of diseases such as malaria and was backfilled after the Second World War. The terrain was subsequently further transformed (mounding, earth depositing, new streets, modified buildings etc.). Site plans and building designations of the old gasworks had only limited value for the localization of soil pollution and the tar pits. The historical exploration of the contaminated site in the archives of the respective offices was therefore largely inconclusive for a long time. Only an extension of the search to the Hanauer city museum founded in 1956, which primarily kept records of the native and ethnographic history of the city, led the experts on the right track.

Figure 5.2-1 Postcards of the area of the old gas factory in Kehl with two gas tanks, on the left of the two photos: the now backfilled channel

Using this historical information, it was concluded that the Kehl gasworks passed into the possession of the French Gaz de France during the occupation period after the First World War (1919-1930). The search for information at Gaz de France and in Alsace archives revealed, however, very little useful information. Either the contemporary witnesses were already dead or untraceable or the archive documents had disappeared almost completely. In addition, a lot of information about pollution had never even been recorded, particularly with regards to accidents and the (for a long time unperceived) groundwater pollution.

Gaz de France had sold the compound again after the end of the occupation period. The site was redesigned afterwards, the "Schuttermühlkanal" was refilled and the area was overbuilt, which posed new questions concerning polluters, their legal successors and the financial responsibility for the remediation. From the late 1990s on, the groundwater contamination was addressed with an active remediation approach, which was then slowly converted into a process of natural leaching (Rügner et al. 2004).

Comments: The example of the Kehl gasworks and the tar oil factory are of interest for the RK&M project for various reasons. The case documents the long timespans during which even conventional waste (tar oils with PAHs) cause serious environmental problems as well as the barely comprehensible, from today's perspective, carelessness when dealing with these wastes. The case also reveals the various, sometimes inter-mingled, factors that led to forgetting the legacy: war, change of ownership, repurchase of the area by German companies after the end of occupation, loss of important information about the gasworks and the tar oil factory by the turmoil of war and the associated migration, the consequent thinning of witnesses, loss of the archives on the French side after the end of the occupation period, and the accidental preservation of information in a city museum company specializing in history and folklore.

5.2.2 Rastatt landfill

Findings: A typical case of loss of knowledge is the case of the drum-store in the "Hintere Dollert" landfill in Rastatt (Baden-Württemberg). During the historical contaminated sites survey the responsible experts believed that the landfill inventory was that of a "normal" municipal landfill and thus could be considered as without special hazard. However, by chance it was discovered that the site had also received drums of chemical waste. The expert in charge discovered the barrel storage within the landfill due to an historical investigation. For verification purposes, he ordered further investigations with geo-radar and geo-electric methods. The expert knowingly reported a wrong location of the drums to the executing company to test the reliability of the test method. Based on the geo-electric investigations the executing company insisted that the drums had to be located elsewhere, precisely at the location that the historic investigations had already revealed them to be.

Comments: The example of the "Hintere Dollert" landfill in Rastatt is of interest for the RK&M project for two reasons. First, it shows that irregularities have happened and do happen frequently when disposing of hazardous wastes, and therefore special attention must be placed on the declaration and incoming control, on independent control mechanisms and structures and on classic archiving of data. Secondly, however, this example also shows that it is possible to back-track wastes if the will is truly there and the necessary resources are made available.

5.2.3 Industrial area in Bad Kreuznach, Rheinland Pfalz

Findings: Bad Kreuznach is located in the district of Koblenz. The superior authority responsible for contaminated sites within the Koblenz district, Structural and Approval Directorate North, suspected waste legacies in an area with industrial companies in Bad Kreuznach. But several inquiries to the municipal authorities yielded no satisfactory results. As a consequence, the experienced surveyor entrusted with the historical survey consulted the Home City Archives, with success. However, the industries still denied the presence of contaminated sites on their ground in 2011.

This example is very typical of the contaminated sites sector and is found in many forms with industries. The responsibility for contaminated sites is always associated with high costs, so industrial enterprises typically oppose any plans by authorities that require investigations or remediation. In this case, finding the truth was not only hampered by the responsible industrial companies, but also not supported by the municipal authorities of Bad Kreuznach, allowed the superior authority to suggest collusion or dependency between the local authorities and the important industries in the city.

Comments: The accumulation of such cases is interesting for the RK&M project in two respects. These examples document a commonly used strategy of industries to play down the danger of wastes and thus to neglect documentation and archives. On the other hand, these examples show that dangerous structural dependencies between waste producers and local authorities arise when financial ties exist (e.g. major taxpayers). In such cases, the administration will pursue short-term interests and stand protectively in front of their industries.

5.2.4 T-acid-production at the Boehringer industrial area in Hamburg

Findings: The industrial area of Boehringer in Hamburg was established in 1951 with the production of insecticides, particularly with Hexacyclohexan (HCH)[5] also known as lindane. The lindane production was associated with very high levels of waste (about 85% by volume), therefore recycling options for these wastes were sought. By means of further chemical recycling, 2,4,5-trichlorophenoxyacetic acid was then won, the so-called T-acid, which in turn was the starting material for a further herbicide and other organic chemical products. Unfortunately, there was also an unwanted by-product: 2,3,7,8-Tetrachlorodibenzodioxin (TCDD), which was quickly recognized as the most poisonous of the over 70 existing dioxin isomers. Until 1953, no health problems among workers involved in the production of T-acid were known. That year, however, the first cases of chloracne occurred at the production site in Hamburg. In the same year there was an accident involving the release of dioxins and the occurrence of chloracne at BASF Ludwigshafen as well. Animal experiments (on rabbits) confirmed the extreme toxicity of the residue.

At the end of 1954, Boehringer therefore stopped the production of T-acid. Studies conducted at the University Hospital Hamburg-Eppendorf, the Hamburg Institute for Wood Technology and Boehringer itself between 1954 and September 1956 proved that TCDD was the cause for the occurrence of chloracne. In 1956, however, the company succeeded in improving the production of T-acid so that it could be considered reasonable and was resumed in Hamburg in 1957. In September 1956, Boehringer planned the publication of some of their findings on dioxins in a medical journal, but prohibited it at the end of October 1956. The representatives of Boehringer later stated that they feared the disclosure of these findings for the foreseeable military and political abuse. However, the publication on the toxicity of dioxins appeared in spring 1957 by the University Hospital Hamburg-Eppendorf and reached a wide medical publicity. Later, this information also made its way to military departments in the U.S. which used the neurotoxin as Agent Orange during the Vietnam War. Boehringer later admitted to having sold the production license for the TCDD-poor method to Dow Chemical, but the company disassociated itself from use of Agent Orange in Vietnam.

The low-TCDD production method continued at the Boehringer Hamburg location until 1984. The environmental damage that was later identified at the site was mainly attributed to the underestimation of the dangers of TCDD and improper handling. An important part of the contaminant outlet was through the sewer systems of the plant. The sleeves of the sewers were not controlled at that time, which made it possible for the pollutant-laden wastewater to propagate into the subsurface. In addition, incidents happened and the storage on the compound was improper. After dioxin-contaminated wastes from the production site in Hamburg were detected in surrounding landfills, the responsible authorities stepped in. In 1984 the plant was closed and cleaned up at significant cost.

Comments: The Boehringer case is interesting for the RK&M project for three reasons. First, Boehringer carried out historical analysis with unusual candor and discovered that documentary material was "carried out of the company and passed on to journalists ". The company could not tell "how many and what kind of documents they were". Secondly, Boehringer regretted the loss of this information for its value in accounting for their own history. Thus, the company made it clear that the archive management had been neglected and that staff had disposed of a large number of documents. Boehringer further pointed out that a definitive assessment of the dioxin-history of the company would be impossible "due to

[5]For an overview, see "Ehemaliges Werk der Fa. Boehringer Ingelheim", http://www.hamburg.de/contentblob/142908/data/boehringer.pdf; Boehringer Ingelheim (1992), Unsere Dioxin-Geschichte, Ingelheim am Rhein: Boehringer Ingelheim (both in German).

incomplete records" and thus pointed out the direct consequences that arise from inferior archives. The company brochure concludes with the observation that it is more than doubtful if there will ever a complete, full documentation of the responsibility of Boehringer Ingelheim for the production and release of dioxin. Thirdly, the Boehringer case study is also very interesting with regards to the handling of knowledge. For one, the leaders were already aware of the unusual dangers of the T-acid in the 1950s, and tried to prevent the dissemination of this knowledge. On the other hand it was the same company that wanted to inform rival companies and that sold licenses to an American competitor. Boehringer was clearly in an ongoing dilemma on how to deal with the knowledge of this highly dangerous product.

5.2.5 Prael in Sprendlingen industrial landfill, Alzey, Rheinland Pfalz[6]

Findings: In Alzey, Rhineland Palatinate, a private owner ran a landfill in an old quarry. Both the local community and large, well-known chemical companies (BASF, Giulini, and Ingelheim Boehringer Mannheim), disposed of their hazardous waste in this pit for years. Some 450,000 t of waste was deposited in the landfill from 1966 to 1972 alone (Siemon and Maier-Harth 2013). The private operator took over the waste, but did no documentation of the delivered or disposed waste. Later the mine owner sold the backfilled landfill to the public sector. As a consequence the landfill had to be cleaned up at great expense using public money: impermeable walls were created and a groundwater remediation was imposed. Issuing a claim for restitution towards the involved waste disposers was unthinkable. The industrial companies involved in the disposal of the waste took the position that they have paid for the proper disposal, and are thus relieved of its responsibility.

Comments: This example shows old traditional practices that have been practiced in many places to hide possible traces for determining the actual disposed waste. This example is of interest for the RK&M project because it illustrates that not only legal deficiencies in the documentation and archiving of the waste inventory are to be deplored, but that planned cover ups of the actual waste legacy have to be assumed. The later sale of the closed clay pit filled with hazardous waste to the public sector provides a clear indication for this.

5.3 Cases of old military legacy in Germany

Severe soil and groundwater contamination caused by the production and processing of explosives came to light one by one in the 1980s. The trigger for the investigation of military sites in Germany was a request of the "Green Party" in the German Bundestag. It set in motion a comprehensive assessment and exploration of armament productions sites (Mangold et al. 1997). In the state of Baden-Württemberg alone six different campaigns for acquiring information on military waste took place between 1990 and 1996 (see table 5-3).

[6] Ministerium für Umwelt und Forsten (2003), Ehemalige Industriemülldeponie Prael, Sprendlingen: Erneuerung und Optimierung der Sicherungsbauwerke, Mainz: Ministerium für Umwelt und Forsten Rheinland-Pfalz (in German).

Date of survey	Project	Number of sites
1/1990	Survey by LfU/RP	84
7/1990	Study for the 2. World War by the University of Marburg	175
7/1991	Survey in the course of the 1. historical preliminary investigation by PGBU	200
2/1993	R&D-Survey Part I: Inventory of suspected sites of military waste in the FRG (assignment by BMU)	224
4/1993	Survey in the course of the continuation of the 1. historical preliminary investigation by PGBU	130
4/1996	R&D-Survey Part II: Nationwide follow-up survey	412

Table 5-3: Suspected sites of military waste in Baden-Württemberg due to various explorations (after Mangold et al 1997.)

Notes for Table 5-3:

BMU = Federal Ministry for the Environment (Bundesministerium für Umwelt),

R&D = research and development;

LfU / LP = Environment Agency / Regional Council (Landesamt für Umwelt/Regierungspräsidium);

PGBU = planning society soil and environment Ltd. (Planungsgesellschaft Boden und Umwelt GmbH)

5.3.1 Bomb craters and bombs

Findings: One particular issue for the survey arises from the large number of bomb craters that were formed during the last two years of war in Germany. The Allied forces conducted aerial photography to determine the damage caused by bombing, giving some information on their locations. These bomb craters and former military installations such as flak positions and old trench systems were filled with rubble and refuse during the post-war reconstruction. This example illustrates the devastating impact of violent conflicts such as war on waste management. In the last years of the war and after the war compiling an inventory of hazardous military waste was not feasible, which is why to this day great efforts are necessary by the public sector to reconstruct the knowledge of these wastes.

In Saxony-Anhalt alone some 45,000 examples of munitions findings can be identified since the end of the war (see Figure 5.3-1). In specific terms, 700'000 shells, 160'000 piece rifle ammunition and 230 bombs were found from 2006 to 2008. Among the 556 km^2 of the contaminated areas in this province about 356 km^2 were considered as rehabilitated up to this point. The cost of these excavations reach the hundreds of millions of Euros for this state alone.[7]

[7]Mitteldeutsche Zeitung (2008), "Köthen wird Bombenlast los", 15 October, accessed 10 January 2013, http://www.mz-web.de/mitteldeutschland/munition-koethen-wird-bombenlast-los,20641266,18289914.html (in German).

Figure 5.3.1: Typical findings of bombs and unexploded dud shot from the Second World War in Germany, left finds from Köthen (Saxony-Anhalt), right from Nuremberg (Bavaria)

Comments: This finding is of importance for the RK&M project. It shows that military conflicts can indeed lead to complete loss of knowledge regarding dangerous goods, weapons or archives. But once lost knowledge can only be restored with great effort and only to a limited extent again. With increasing temporal distance to the events (in this case, the Second World War), the additional problem of finding witnesses and the lack of documentation is found in an intensified form.

5.3.2 US battle tanks – Karlsruhe Knielingen barracks

Findings: A completely different example is presented to us by the U.S. tank barracks at Karlsruhe Knielingen, which the American troops left behind in 1995. Groundwater studies, which were done after the evacuation of the barracks, reported enormous quantities of hydrocarbons from the tank barracks, seated on the groundwater up to several metres in depth. The cause of this dramatic pollution was eventually determined by intensive questioning of former employees. At the Karlsruhe Knielingen tank barracks the delivery of gasoline for the tanks was strictly regulated and subject to quotas. Every week the required fuel was delivered by rail. There was only limited storage space for the delivered fuel available, but it was mandatory to accept the weekly deliveries, therefore there were frequent excesses of gasoline, which could no longer be returned to the supplier, but were simply dumped into the ground on site. In a week during which there was little driving of the tanks, large amounts of gasoline were introduced into the ground this way.

Comments: This case is interesting for the RK&M project because it identifies and documents human error as the source of the problems once again. Military regulations prevented environmentally sound management of the delivered fuel. The practice was in place until the barracks were vacated. Later studies of the groundwater showed up the damage. In this case nonsensical regulations, the stubborn adherence to these rules, convenience and a lack of responsibility for the environment led to this damage event. The pollution was not recognized for this long due to the fact that the poor practice was not documented, and information about the groundwater polluting practice could be suppressed by the military authorities for a long time.

5.3.3 US Karlsruhe Ettlingen barracks

Findings: A similar contamination of the sub-surface could be demonstrated at the American barracks in Karlsruhe Ettlingen. Heavy vehicles were refueled in these barracks, but the gas station, the operating room and the garage date back to the 1930s. Investigations of the soil around the year 2000 showed that the hydrocarbon contamination of the sub-surface reached much deeper than originally thought. Liquid phase petrol was finally found in 25 metre deep boreholes. This had been used as a fuel for Traxters (racing carts). The liquid phase was subsequently siphoned off and the base rehabilitated by means of ground-air treatment.

Comments: As in section 5.3.2, in this case human inadequacy was the origin of the contamination. The military authorities in charge knew that mineral oils were dangerous for the environment, but did not take responsibility for spillages. Fuel tanks were filled until the tank ran over and the gasoline seeped into the ground, but the personal responsibility was not recognized and users claimed that "everybody does it". As is typical with such cases, these incidents had not been documented, but had to be reconstructed by later interviews of witnesses and investigations. The incidents were covered up, reinforced by the fact that the responsible agencies were, at least in principle, aware of the abuse.

5.4 Cases of loss of information, records, knowledge and memory in the USA

5.4.1 Waste dump at Love Canal, Niagara Falls

Findings: The waste dump of Love Canal in Niagara Falls reached international celebrity in the 1970s and 1980s. The case of the landfill was traced in great detail in a remarkable scientific investigation (Levine 1982). In brief, many of the issues raised in other contamination and landfill cases in this report are repeated here. The Love Canal was partially built, but never completed, in connection with the electrification of the late nineteenth century and the settlement of industries. Until the Second World War, the 1000 m long, 20 m wide and 3 m deep canal served as a recreational area. Then an electrochemical plant in the vicinity had the idea of using the channel as landfill. It managed to buy parts of the channel and to deposit its highly toxic waste there between 1942 and 1953. A total of approximately 21,000 t of toxic chemical wastes were dumped in barrels and covered with a clay layer. As usual at this time, the company did not file any landfill register on stored waste, thus the information on the contents of the filled channel remained very limited. Given the strong economic growth after World War II, combined with a rapidly expanding urban development, the Love Canal site was sold. In 1953, the company managed to sell the roughly 64,000 m^2 of land to a public school, for the symbolic price of 1 dollar.

In the purchase agreement, the company assured itself against potential subsequent lawsuits, by terms that prevented it being exposed to possible damages in the future. The area was generally overbuilt: along the canal houses emerged, on the refilled channel itself a school was built. Drums or their contents began to come back to the surface, causing serious illness and sometimes even deaths among residents of the area and school children in the vicinity of the old channel. In the following years and decades, the case was investigated by the U.S. Environmental Protection Agency. The case of Love Canal had a decisive influence on the law adopted in 1980 to protect against and for the remediation of contaminated sites (Comprehensive Environmental Response, Compensation and Liability Act [Cercla]).

Figure 5.4.1: Some images of Love Canal during and after the clean-up (photos from Internet)

Comments: The case of Love Canal points to another aspect, which is of importance for the RK&M project. Besides well-known factors such as lack of or improper storage cadastre or sparse to non-existent documentation, the case of Love Canal points to other key features that show how information can be lost.

The deposition of chemically toxic waste at Love Canal was known far and wide in the city of Niagara Falls. The knowledge about the dangers of the waste in the channel was present in both the selling chemical company (which was provided protection by agreement), and the buyer, the School Board of Niagara Falls, that bought the entire site for the symbolic sum of 1 U.S. dollar. Both sides wanted to know as little as possible of the hazardous nature of the waste.

The risks had been consciously or unconsciously repressed, underscoring the inexperience and ignorance of the school authorities about the danger. The competent health authorities did not intervene either. Even the best archives would probably not have led to a different outcome. The priorities of the city were set and superseded other interests, such as the protection of human health and environment.

Even today authorities as well as normal citizens systematically underestimate the real dangers of waste. It is not enough to ensure documentation and archives on dangerous legacies. It is equally important to transfer knowledge about the hazards of substances over time. We are dealing with a classic case of semiosis here, in which the sender needs to pass substantive knowledge about hazards on to the recipient over longer periods of time. The existence of documents and archives far from ensures the passing on of this knowledge.

5.4.2 Toms River waste dump, Dover Township, New Jersey

Findings: The Ciba-Geigy Corporation site at Toms River is another instructive example for the handling of hazardous wastes and information. From 1952 to 1988/1990, synthetic organic pigments, organic dyestuffs and epoxy resins were produced on the site (EPA 1989). The liquid or solid production wastes were retained in a lagoon on site, or disposed to landfills with drum deposits. Even though groundwater wells in the effluent production area showed signs of contamination shortly after setting up the lagoons and barrel storage, neither the owner nor the competent authorities for the drinking water stepped in. Only the growing volume of complaints from neighbours and well owners, and serious health consequences in the population, led to the intervention of the local environmental protection agencies, and soon after the intervention of the U.S. Environmental Protection Agency.

In 1983 the authorities of New Jersey decreed that the operator must not accept any more liquid waste for treatment in the waste water treatment plant. Inspections in 1984 showed, however, that Ciba-Geigy continued to deposit liquid wastes at the site. The investigation initiated by the authorities eventually led to the indictment of several Ciba-Geigy officials, who were charged with the illegal disposal of chemical waste, the filing of false documents with the NJDEP, making false and misleading statements to the NJDEP, and the illegal disposal of hazardous waste (EPA 1989, p.4).

Comments: In the case of Toms River we find the known and usual "ingredients" in dealing with waste legacies: faulty or missing documentation from the early days, incomplete archives, inadequate tracking of documentation, defensive attitudes towards clarification, and a lack of resources. One aspect of the case of Toms River case is exceptionally dramatic.

The cases described so far in which illegal handling of waste could be demonstrated concerned rather dubious companies or poorly structured and controlled projects (see the cases of the Fabrique de Chaux or the Bärengrabens in Würenlingen). But in the case of Toms River, it concerned a leading multi-national, internationally recognized company with high reputation. That such a company allows forgery of documents and false declarations during an official criminal investigation raises fundamental questions with regards to the truthful use of information and records. It shows, like the cases in the international banking community (e.g. manipulation of the Libor rate), that the field of manipulating data, information and archives is much more extensive into established economies then commonly assumed.

5.4.3 Injection of toxic waste fluids in deep injection wells

Findings: A particularly interesting example for the handling of waste is the injection or seepage of liquid hazardous waste. In the early days of nuclear usage we see cases of systematic "disposal" of liquid radioactive wastes by seepage and dilution as well (e.g. sites at Hanford [Washington] and Oak Ridge [Tennessee]) in the western hemisphere. In the former Soviet Union and today's Russia, liquid radioactive wastes are still injected into the deep underground.

This technique, originally applied in the petroleum industry, spread to other industries. Injection is employed in the US for more than a hundred years, although but warnings about long-term contamination of the drinking water reserves persist (cf. Scientific American 2012).

The problem of waste injection in the underground is significant because of its scale. It has been calculated, that "more than 30 trillion gallons of toxic liquid"[8] have been injected into the deep underground. "There are more than 680'000 underground waste and injection wells nationwide, more than 150'000 of which shoot industrial fluids thousands of feet below the surface" (Scientific American 2012).

[8] Around1014 l or 1011 m3

Comments: The injection of fluid toxic wastes in deep injections wells worldwide yields two further findings for the RK&M project. First, this example shows that the amount of information is so large that lost knowledge about the injection practices and the wastes is inevitable, and cannot reasonably be reconstructed. This problem is, in reduced form, also relevant for the nuclear industry.

Second, it raises another fundamental problem that is unlikely to be tackled by the nuclear community in the foreseeable future. Future generations will wonder why the nuclear community warned about the dangers of deep nuclear repositories, whereas non-nuclear industries polluted deep groundwater resources for long time periods. In this context, the nuclear side needs an answer in terms of an understandable culture of memory.

Figure 5.4-3: Deep well injection techniques for hazardous and toxic waste fluids (http://water.epa.gov/type/groundwater/uic/wells_class1.cfm#what_is)

5.5 Loss of information, records, knowledge and memory by dumping wastes into the sea or into lakes

5.5.1 General strategy of dumping military wastes (munitions, shells etc.) into sea

Findings: A particular form of waste disposal, which was practiced worldwide, especially after World War II by many National Defense Departments, was sea dumping. Older military munitions were simply dumped into the sea, including: chemical munitions like mustard or nerve gases, rockets, ballistic and guided missiles, bombs, artillery ammunition, grenades, mines etc. (Carton 2009). In addition to munitions some radioactive wastes were also dumped at sea (IAEA 1996; Davis and van Dyke 1990). Dumping locations were sometimes, but not always, reported to national hydrographic offices.

Larger amounts of military wastes were dumped after World War II until 1972, when the Marine Protection, Research and Sanctuaries Act was adopted in the USA. Depths of dumping areas ranged from some tens of metres to thousands of metres. The dumping locations are poorly known "because of navigational errors and inadequate record keeping" (Chin and Otta 2001). Furthermore, sea currents have scattered the wastes during the sinking process as well as through slipping along continental slopes. The historical reconstruction of the inventories, the state of the military wastes and the waste locations will thus remain poor and difficult to reconstruct.

Comments: There are several lessons for the RK&M project to keep in mind from these insights. First of all, military wastes were dumped under constraints, some of which were just technical ones, such as safety considerations with expired explosives. Other reasons were technical development of new weapon and ammunition generations, overcrowded ammunition stocks that urgently needed to be reduced, and financial considerations in order to insure lowest cost "solutions" at the back-end. Once more, dumping wastes was the easiest and cheapest way to dispose of these challenging wastes.

Other reasons of concern include the administrative routine of the authorities, lack of environmental awareness or simply convenience. Under these conditions, information transfer and knowledge preservation was difficult to ensure. The loss of precise information and knowledge about wastes, technical data and disposal areas in these cases must be assigned mostly to human deficiencies.

5.5.2 Military wastes (munitions, shells etc.) in Swiss lakes

Findings: From the First World War onwards the Swiss army manufactured their ammunitions in plants in Thun (Canton of Bern), Altdorf (Uri) and Wimmis (Canton of Bern). From the start these companies disposed of their production residues, off-specification batches and waste directly into the lake. Over time, another category of waste followed: ammunition stock from the fortifications of the so-called Réduit, the Swiss defence concept during World War 2. The military authorities underestimated the risk of underground storage, until the catastrophe at Mitholz underground ammunition storage (Kandergrund, Bern, see figure 5.5-2). This disaster had an immediate effect on the dumping actions of Swiss ammunitions in lakes.

The sudden detonation of around 7'000 t of ammunition on the night of December 19th 1947 at Mitholz underground ammunition storage caused 9 deaths, destroyed many houses in the neighbourhood and led to damage costing more than 100 million Swiss francs. The accident of Mitholz is considered to be a major incident among man-made non-nuclear detonations (Rytz and Bakhtar 2010).

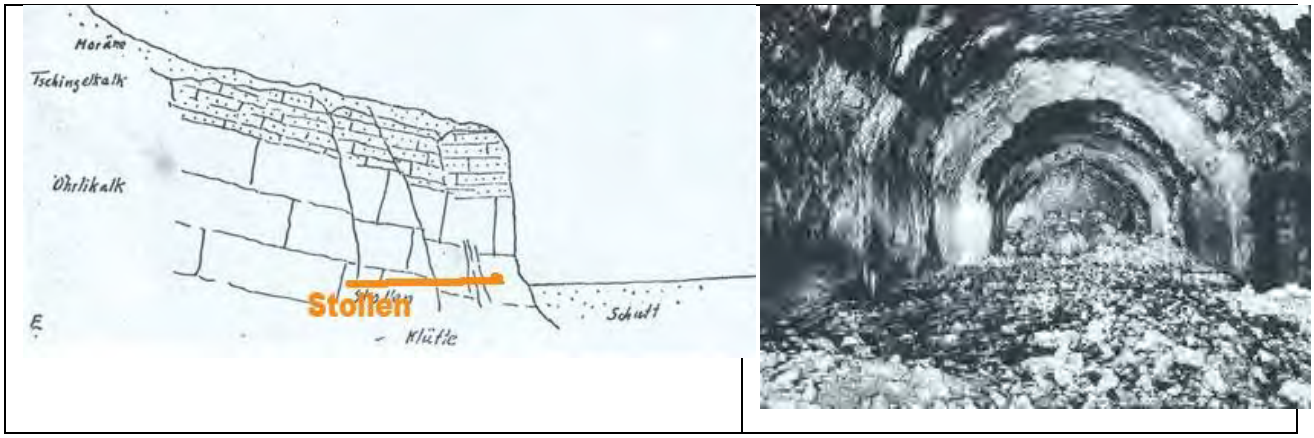

Figure 5.5-2: 1947 drawing of the storage cavern of Mitholz (Kandergrund, Bern, left) and the cavern after the incident (right), from www.festung-oberland.ch/

The accident of Mitholz had immediate consequences: The Swiss army audited the whole concept of ammunition storage and decided to discharge a major part of the existing ammunition stocks into the lakes of Thun and Brienz (both canton of Bern) and at two places in the lake of the four forest cantons (central Switzerland) in depths of some hundreds of metres. More than 8'000 t of stocks from different ammunition depots were dumped within half a year after the accident. Later investigations examined whether or not detonators had been included in the disposals (Schenker Korner & Partner and Van Stuijvenberg 2012). The munitions factories continued their practice of lake dumping their waste even after the Second World War, in Altorf until 1961, in Thun until 1967. The Bernese authorities supported these dumpings unconditionally, whereas the authorities in Uri were a bit more critical towards the dumping actions. There

was a change in the management of the munitions factory of Thun in 1967. The new management stopped the lake dumping practice immediately.

After dumping of ammunition in lakes was no longer possible, the expired ammunition was blown up, first in the Gasterntal (Canton of Bern), later at the Susten pass (Canton of Bern). Only later was the ammunition properly handled, blown-up and disposed of on the ammunition plant site. In 1992 it was announced in the press that ammunition wastes had been dumped into Lake Thun during the production period. Federal councilors wanted clarification on these incidents, and environmental officers of the Department of Defence, Civil Protection and Sport (DDPS) were invited to make brief reports on hazardous waste and waste legacies of the army. This was the forerunner of today's cadastre of contaminated sites. But these investigations were not really perceived by the public.

Around the year 2000, fishermen of Lake Thun alerted the general public concerning deformations of the sexual organs of whitefish. In the context of further investigations, the dumped ammunitions were among the potential causes of the problem. Some years later, in March 2004, a local television broadcaster brought the dumped ammunition to public awareness. A witness reported that very large amounts of the former army stocks had been dumped, a statement that had to be put into perspective later.

Another case of dumping ammunition in lakes is reported from the Canton of Zürich. The dumping of ammunition from the industrial weapon production of the Swiss manufactory Oerlikon Bührle & Co., started in 1936 and was stopped in 1966. During this period some 90 t of ammunition was dumped at three places in the central part of Lake Zürich. Fishers were quickly aware of the potential risks - hazards that seem to be negligible in reality (Baudirektion Kanton Zürich 2007).

Comments: It appears that the disposal of ammunition by dumping in Swiss lakes was done under severe pressure. After the accident of Mitholz, the Swiss army seriously questioned the safety conditions of ammunition storage in caverns, and quick solutions were requested in order to reduce a risk that appeared to be unacceptable. The decisions were taken under consideration of the imminent potential explosion hazards of the existing stocks, leaving ecological considerations beside. Moreover, waste disposal was also admitted to be extremely cheap, a strategy that was also applied in the conventional land dumping. Except for archival storage, no specific actions were taken in order to preserve data, information and thus knowledge about the dumping and the evolution of the submerged waste.

Moreover, the knowledge-holders of this early phase of waste disposal were lost during the reform of the federal pension plan in the years following the first effects of the new bubble economy. The retirement schemes were reviewed and the conditions severely re-adjusted. Officers could chose to go into retirement from 60 years of age with better financial conditions under the old regime, or work 5 years more and have a smaller retirement pay. It was an obvious choice, and federal officers left the offices in droves. Within a few years, RUAG, the former armament company of the Swiss Confederation, had lost most of its "living memory".

6 CONCLUSIONS AND OUTLOOK

Waste is a material that inherently has 'no value', so the prevailing philosophy has been that its disposal must be without cost, or at the lowest possible cost. Lndustrialisation led to a massive increase in the scale and toxicity of the waste problem. Traditional approaches to the handling of wastes are simply to dump them in an uncontrolled fashion, on the basis that the environment has a capacity to absorb, degrade and disperse the wastes. History has shown that the challenges presented by technological wastes are only addressed properly when strong regulation and appropriate sanctions are in place. Recently, the environmental movement has played a significant role in focusing attention on proper waste management and records.

This study was based on 21 examples of conventional (non-nuclear) waste disposal in Switzerland, Germany and USA. These examples were all drawn from industrial and military processes, but were operated by a range of landowners, including national government, local authorities, private companies and individuals. Each of them had a history in which the original waste disposal practice was forgotten or details had been lost, resulting in uncontrolled environmental contamination and costly clean-up.

The 21 examples were drawn from a very large number of known disposal sites. It is considered that although only a small number of examples was analysed, the range of wastes and waste management practice was sufficiently broad to indicate trends and allow firm conclusions to be drawn.

A key conclusion from this study is that it is rare to lose all information about waste disposal, but that the details tend to be lost first. It is also clear that many records are made with insufficient data to inform remediation actions, and that once lost, records are very difficult to re-construct.

The study was based on identifying the key factors that are considered important with respect to the loss of knowledge. These were defined as:

- Technical / environmental factors
- Economic factors
- Human factors
- Structural factors
- Regulation / laws

A number of sub-factors were identified under each of these headings, resulting in a total of 18 specific reasons for memory loss, as shown in Table 6.1. Each of the 21 examples was analysed against these 18 reasons, and many of them showed multiple reasons for memory loss. Four of the reasons were identified as relevant contributory factors in every one of the 21 example cases. These are:

- No records or poor archives
- No / insufficient update of records (e.g. maps, plans)
- No / insufficient budgets to fulfill the duties
- Personnel changes

These four were drawn from the technical, economic and human factors groups. It is clear that the failure to make records or to keep them updated is likely to result in loss of memory, as there is no primary record to refer to. The absence of a budget to cover the costs of record-keeping is also likely to result in memory loss. Changes to personnel are often accompanied by poor handover arrangements, which are likely to result in rapid loss of memory.

Although they occurred more rarely, two of the other reasons are considered to be particularly significant. These are:

- Illegal activities
- Societal discontinuities

The first involves the deliberate, unlawful loss or destruction of records, usually motivated by financial gain. The second relates to major societal upheavals, such as war and the shift of national boundaries, which are likely to be accompanied by a transient change of priorities. It is clearly difficult, if not impossible; to prevent these two factors occurring simply by creating management systems.

Finally, this case study provides some key insights for the future management of information and archives, and for maximizing the potential for successful retention of knowledge and memory. It is important to recognize that the bodies responsible for the nuclear industry will have to address the problems related to the preservation of knowledge and memory in a very fundamental and pro-active way. It is still unclear to what extent policy makers and authorities in the nuclear field are really aware of the importance of preserving knowledge and of the necessity to build up a culture of memory.

As the history of landfills shows, failures in the past with regards to information and knowledge management are largely responsible for the problems and the subsequent costs of remediation programs. From this perspective it is essential to supplement the existing laws of those countries that utilise nuclear energy, in order to store relevant knowledge for the future.

Table 6.1: Summary of the case studies treated and key factors for loss of records and knowledge

	Key factors for loss of records and knowledge	St.. Ursanne	CISA Bonfol	DIB Bonfol	Region of Basel	Riet	Bärengraben	Tössegg	Hardwald/Hombera	Kehl	Rastatt	Bad Kreuznach	Boehringer Hamburg	Prael	Bombs	Knielingen	Ettlingen	Love Canal	Toms River	Injection wells	See dumping	Dumping in lakes
1	**Technical / environmental factors**																					
1.1	Site degradation (partly also of technical installations)	x		x	x	x	x	x	x	x			x					x	x			
1.2	Re-cultivation of old disposal sites / camouflage	x		x	x			x	x	x				x	x	x	x	x	x			
1.3	No records or poor archives	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1.4	No / insufficient update of records (e.g. maps, plans)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1.5	Loss /destruction of archives	**x**	**x**	x	x	x	x	x	x	x			x							?	?	?
2	**Economic factors**																					
2.1	No / insufficient budgets to fulfill the duties	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3	**Human factors**																					
3.1	Personnel changes	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.2	General dis-interest in the area of RKM preservation	x	x	x	x	x	x	x	x			x		x		x	x	x	x	x	x	x
3.3	Negligence in the accomplishment of duties	x	x	x	x	x	x	x	x			x	x			x	x	x	x	x	x	x
3.4	Ignorance and/or incompetence	x		x	x	x	x	x	x			x				x	x	x	x	x	x	x
3.5	Arrogance			x	x											x	x		x	x	x	
3.6	Underestimation of effective risks	x		x	x	x	x	x	x	?	x	x	x			x	x	x	x	x	x	
3.7	Misunderstanding of information and records									x												
3.8	Illegal activities (e.g. falsification of documents, unauthorised disposal)	x		?	?		**x**							x		?	?		**x**	?	?	
3.9	Deliberate restraint / manipulation of data, information and records			?	?		**x**					?		x		?	?	?	**x**	?	?	
4.	**Structural factors**																					
4.1	Discontinuities (e.g. war, crisis, bankruptcy)	x	x	x						**x**											x	x
4.2	Structural deficiencies (e.g. lack of structural competence)	x		x	x	x				**x**		x		x	x	x	x	x	x	x	x	x
4.3	No / poor structural continuity	x	x					x	x	**x**		x	x	x		x	x	x	x	x	x	x
5	**Regulation / laws**																					
5.1	Lack of regulation / laws	x		x	x	x	x	x	x	**x**	x	x	x	x		x	x	x	x	x	x	x
6	**Coupled processes**																					
6.1	Any combination (e.g. ignorance and economics)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

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