Thai-German Research Project WADIS Recommendations for the investigation of Abandoned and Proposed Waste Disposal Sites in Thailand

Dr. Juergen Lietz[1]

Abstract

Many waste disposal sites in Thailand are sources of environmental pollution because domestic as well as industrial waste has been largely disposed of in the past without effective safety and control measures.

The Thai-German Research project "WADIS" is jointly carried out by the Department of Mineral Resources (DMR) and the Federal Institute for Geosciences and Natural Resources (BGR) The project focuses on the risk assessment of abandoned waste sites as well as on the Multi-Barrier-Concept for the selection of new waste disposal sites. The Multi-Barrier-Concept includes besides technical barrier (made by man) also the natural rocks below a waste site as an important barrier and safety system against contaminant spreading and groundwater pollution.

The WADIS Project has so far selected two abandoned waste sites near Chiang Mai as pilot sites for the exemplarv investigation of their geological and hydrological setting and for risk assessment. The surveys comprise geological, geophysical, hydrogelogical and laboratory investigations supported by drilling of groundwater monitoring wells. Know-how and technology transfer as well as the the provision of a handbook for site investigations are major objectives of the project.

Introduction

A clean environment belongs to the most valuable assets in our world. Regrettably however, the world has to fight more and more causes for environmental decline and poorly managed disposal of waste is one of these causes.

The rapid growth of urban and industrial areas in fast developing countries1ike Thailand is very often and rather visibly expressed in strongly increasing amounts of waste which have to be managed and disposed of in a way that environmental pollution is avoided or at least kept at a minimum. This is a huge and challenging task for every authority concerned. If the waste is not treated and disposed of correctly it will cause undoubtedly serious environmental problems. Some of these problems (odor, scattering, surface runom are directly perceivable and can be acted upon accordingly. But others are far more dangerous because they are hidden and not immediately apparent to our eyes.

This is especially the case of groundwater pollution through waste site leachate. Pollution occurs in the subsurface fast or slow but always as a process with possible 1ong-term impacts. Not without reason is waste therefore, often referred to an "ecological time bomb" which poses a serious threat to the

[1] Federal Institute for Geosciences and Natural Resources (BGR)

environment and human health. It must be our responsibility and obligation to minimize or avoid this threat.

The implementation of such a task is not only a challenge to environmental engineers and law makers, but also to geo-scientists. Mitigation and prevention of groundwater pollution demands a good understanding of the geological setting and the hydrological processes in the subsoil. This knowledge is most competently provided by geo-scientists. Their experience and methodical approach is indispensable in the field of waste site safety and groundwater protection. The Thai-German Research Project WADIS (waste disposal) has taken up this challenge.

Aspects of waste disposal in Thailand

Waste disposal sites are still an indispensable part of the infrastructure for Thailand's rapidly growing urban society. Despite strong efforts in waste reduction through avoidance, reuse, recycling and composting, the demand for new landfill sites is ever increasing. Today, nearly 14 million tons/year (about 40.000 t/d) of waste are generated out of which 1-2 millions tons are hazardous industrial waste. Estimates indicate that these figures will further grow in the future.

As a result, the search and provision of land for the construction of new waste disposal sites is very high on the agenda of all local authorities responsible for waste management. But very remarkably, the issue of site selection has become one of the most difficult and sensitive topics in local politics.

The reasons for this development are manifold. One important factor is, that in the past (and still today) waste has been mainly disposed of without effective safety and control measures leading to strong negative impacts on the environment (groundwater, soil, surface water, air) and on human health. This has led in the eyes of the public to a very negative perception of waste management and to a loss of confidence that these circumstances will change quickly.

Figures from the Pollution Control Department indicate that until lately more than 60% of Municipal Solid Waste (MSW) has been improperly disposed of and the construction of "sanitary landfills" lacks far behind the demand. A comprehensive survey carried out by the Pollution Control Department in 1998 shows that at numerous waste sites in northern and central Thailand groundwater has been significantly contaminated by heavy metals and other harmful substances through waste site leachate.

Other alarming figures suggest, that out of yearly 1-2 million tons industrial waste more than 50% are unaccounted for and have been most likely disposed of without proper treatment in MSW landfills or other dump sites. Moreover, MSW has not been classified until now as a possible pollution source. Consequently, site selection and construction does not require a mandatory Environmental Impact Assessment (EIA), though MSW composition has certainly changed by growing input of hazardous substances from the city areas and their surroundings. This situation is aggravated by the practice (at least in the past) of mixing MSW with industrial waste and its dumping in MSW landfills

A further issue of concern is the general modus of selecting an area for a new waste disposal site. Guidelines have been published by the Pollution Control Department in 1998 containing among other technical directives also instructions for the consideration of geo-scientific factors in site selection, like depth to groundwater and permeability of underlying rocks. However, despite these stipulations, the final decision for the selection of a specific site is very often determined by different factor.

All these circumstances have contributed to the perception that waste disposal sites in Thailand are still rather poorly managed facilities and sources of serious environment pollution. As a result, affected people have adopted the tactic of strong protests and today nearly every newly proposed waste site becomes a target of people's opposition. Such actions might create local results when authorities have to back down from their original plans but in the 1ong run this approach will only aggravate the problem by leading to more clandestine methods of waste disposal or to the extension of already grave situations at existing sites.

There can be no doubt that a change in the public perception of waste disposal management is highly desirable. The already mentioned steps as well as efforts to integrate the public at an early stage into the decision making process are encouraging. But the issue of sustainable waste disposal is complex and not entirely related only to social and legal aspects or awareness raising. It is also strongly related to the decisive knowledge and management of geo-scientific factors during the process of waste site selection, construction and monitoring.

Objectives and Strategies of the WADIS Project

The overriding goal of the WADIS Project is to enhance the safety precautions for waste disposal sites in Thailand. Main objective is the protection of groundwater resources from hazardous waste site impacts. Different strategies have been selected to achieve this target:

First strategy

is the exemplary investigation of already **existing waste disposal sites** as potential sources of long-term pollution. The project has selected for this purpose two abandoned waste sites: "Mae Hia" and "Nong Harn" in the neighborhood of Chiang Mai. These two waste disposal sites of Chiang Mai municipality are the test sites for comprehensive geo-scientific studies supported by the application of a wide spectrum of state of the art technologies for site investigations. Assessment of the hazard potential and possible recommendations for mitigation or rehabilitation measures will be an important output.

Second strategy

is the exemplary investigation of areas where **new waste disposal sites** are considered. Established criteria will be applied for the suitability of such areas from the geoscientific point of view. Focal point is the proper investigation of the subsoil conditions below and in the surroundings of proposed sites. This is important because the natural rocks in the subsoil can act as an effective barrier **(geological barrier)** against contaminant spreading if they meet the following conditions: absence of a major aquifer, 1ow permeability/high clay permeability/high clay content, sufficient thickness and extension, retention capacity for contaminants.

The safety aspects of the geological barrier are part of the **"Multi-Barrier Concept"** for waste disposal sites. This concept focuses on high safety standards and comprises technical or man made barriers (e.g. liner systems) as well as the geological barrier in the subsoil. Should the technical barrier at the bottom of a waste site fail, the geological barrier can still act as a crucial safety system which provides sufficient time for risk analyses and remedial action

Third strategy

is the compilation and edition of an **Investigation Handbook** comprising three volumes:

The volume **Methods** will document the spectrum of state of the art methods in waste site investigations ranging from preparatory desk studies to detailed applications like: remote sensing, ground geophysics, drilling and completion of monitoring wells, field and laboratory analyses as well as modeling of groundwater flow and contaminant transport.

The volume **Case Studies** will describe in exemplary form the investigation results from selected test sites by highlighting also advantages as well as limitations of the applied methods. This approach will sharpen the understanding for the applicability of certain technologies and will provide criteria for target oriented and cost effective use

The volume **Recommendations** will integrate main topics from the other two books while focusing primarily on recommendations which deem appropriate and cost effective under existing conditions in Thailand.

Investigation Sequence

For the systematic investigation of waste disposal sites the project follows a sequence of investigation steps which are briefly summarized:

1. Desk studies

Desk studies aim at the compilation and assessment of already available information (maps, reports, publications, archive records etc.) including information from contemporary witnesses.

2. Remote Sensing

Remote sensing is a highly useful tool in studying the selected target areas in a wider setting with regard to infrastructure, topography, land use, structural patterns and flooding hazards. Satellite images as well as air photos are used for these purposes.

3. Base Maps

The provision of updated base maps in suitable scales (1:5000 and larger) is the most basic precondition for all technical investigations. It is a common experience, however, that such detailed maps are only rarely available and even smaller scale base maps (1:50,000) are often quite outdated. Under such circumstances, suitable maps have to be prepared with the support of recent air photos, high resolution satellite images or by geodetic ground surveys

4. Field Mapping

Geological field surveys are necessary to improve the given geological information or to compile even new geological maps. Equally important is the compilation and updating of information about existing groundwater wells and other water supply facilities.

5. Ground Geophysics

It has been demonstrated in the past that methods of ground geophysics (e.g. seismic, electric, magnetic, gravity, electromagnetic) are useful tools for an assessment of the subsurface. Compared to boreholes, geophysical methods are indirect methods but with the advantage to provide rather quickly integrated subsurface information across a larger study area in a cost effective way. Boreholes, on the other hand, yield more direct information with often high accuracy. However, the information is generally restricted and therefore often non representative for a wider area.

In practice both exploration methods are applied to complement each other. Borehole data are taken to calibrate geophysical results and geophysical information is used to extrapolate borehole data into the wider subsoil. Both methods can be applied in a strategic and cost effective way

Within the field of waste site investigations ground geophysics can be applied with the following objectives:

- subsurface geological setting
- depth to groundwater
- detection of contamination plumes
- location of abandoned and possibly built over waste sites
- screening of burried objects

At research level the WADIS Project applies the following geophysical methods:

- Seismic
- Gravity
- Magnetic
- 2D-Resistivity
- Resistivity sounding
- Electromagnetic

6. Well Drilling

After obtaining information on the geological setting and the presumed groundwater pattern through field studies and ground geophysics wells are drilled at strategic locations and completed as groundwater monitoring wells. Number and depth of these wells depend on the scope and quality of the existing information. Cores, well logging and hydraulic tests yield valuable hydrogeological information as well as detailed data for the calibration of geophysical results.

7. Hydrogeological Investigations

Data obtained from monitoring wells improve together with geophysical information the knowledge about the local groundwater system and its risk of being affected by waste site contaminants. Groundwater level recording, delineation of flow directions and assessment of hydraulic tests will facilitate groundwater flow models and scenarios for possible contaminant transport.

8. Lab Investigations

Lab investigations comprise chemical analyses of water samples from monitoring wells, from waste site leachate as well as from surface water near the sites. In addition, flow passage tests of core samples give more detailed information about the quality of geological barrier rocks, the transmissivity of aquifers and about their retention capacity for contaminants.

An accurate understanding of the contaminant inventory as well as its distribution and movement in the subsoil is important to characterize and qualify an impending risk.

Preliminary Results

A brief summary of so far achieved results is given from the two selected test sites "Mae Hia" and "Nong Harn". The results and interpretations are still tentative because the investigations are presently going on and will only be completed in 2003.

Waste Disposal Site Mae Hia

The Mae Hia site (about 6 km SW of Chiang Mai) served for about 3o years as the main open waste dump of Chiang Mai municipality. It was closed in 1989 due to strong protests of the people from nearby villages. Stench, noise and suspected water contamination of shallow dug wells were reasons for the closure. The water supply of the villagers had to rely at this time only on numerous dug wells with some of them close to the waste site. Today, the villages surrounding the disposal site are connected public water supply, but some dug wells are still in use for 1ocal irrigation purposes. Studies about a possible contamination of the dug wells through waste site leachate were carried out by Karnchanawong et al in 1993 and 1999.

Geophysical results and well data of the WADIS Project provide for the first time a more detailed insight into the geological setting in the surroundings of the waste site and permit a first, however, still tentative assessment of the impact on the groundwater resources.

Seismic evidence shows that the subsurface geological structure consists of two major sediment sequences which are separated by an unconformity. Fault zones as well as horst and graben structures with likely influence on the groundwater flow pattern can be delineated.

Geoelectrical results clearly define the boundaries of the former waste depocenter and indicate that the surrounding rocks consist predominantly of fine grained clay rich sediments which might act to a large degree as a geological barrier against far reaching contaminant spreading.

Drilling results from monitoring wells confirm the predominance of clay and silt rich sediments as well as the likely absence of major regional aquifers.

Chemical analyses of groundwater which was taken from 9 new monitoring wells during a first sampling campaign in April 2002 permit the distinction of 3 different groups: not affected, affected, and possibly affected. However, the overall concentrations of measured substances are generally so 1ow that a distinction between waste site origin or possibly local anthropogenic impact is difficult to make. More investigations will be carried out also with groundwater sampling during different seasons of the year.

The inferred impact of waste site leachate on dug wells towards the east of the waste site (as reported in earlier studies) will be investigated by the project in more detail with the help of shallow observation wells. Apparent surface contamination of many of the open dug wells impedes a reliable interpretation of analytical data.

Waste Disposal Site Nong Harn

The Nong Harn site (about 16 km NE of Chiang Mai) was selected in a former borrow pit of about

100x100 m length and 40-50 m depth. The waste site was designed and constructed as a sanitary landfill with HDPE base and wall liner and a leachate collection and treatment system. Nong Harn was operated as the municipal waste site of Chiang Mai from 1995 to 1998. By then, the former pit was filled up and covered with a soil layer. Since the closure of the site the surface layer is strongly subsiding due to waste compaction. Today, a lake has developed at the centre of the site.

Seismic evidence provides rather detailed information about the geological structure in the surroundings of the waste disposal site. The subsoil sediments can be differentiated into three major sequences above inferred "basement rocks." The sediments consist of clay rich colluvial sediments with different degree of compaction.

Geoelectrical surveys could so far not detect a significant contamination plume outside the waste site boundaries. This suggests that the installed liners and probably even more the barrier function of the sediments in the subsoil provide a fairly tight environment against widespread leachate migration.

Chemical analyses of groundwater samples from a monitoring well which was drilled by the project close to the northern rim of the waste site show slightly raised parameter values indicating a waste site origin. Two more strategically located monitoring wells will be drilled in order to scrutinize these observations.

Magnetic surveys revealed a surprising result. Profiles across the waste site display a very strong magnetic anomaly which cannot be correlated with any geological cause or with customary magnetic anomaly patterns for municipal solid waste. The strong anomaly appears only correlatable with an unusual high amount of ferromagnetic material within the waste body itself. A modeling approach puts the source of the anomaly into a layer at about 30 m depth and with a thickness of about 15 m. The nature of the magnetic material has so far not been identified but the presence of industrial sludges and/or steel drums cannot be excluded.

Waste site gas is a further alarming aspect at the Nong Harn site. The gas is generated through the decomposition of organic waste. It consists of up to 61% methane and up to 37% CO_2. Strong gas emissions together with dark brown leachate occurrences are clearly visible at the surface of the waste site.

However, gas migration takes not only place in a vertical direction but migrates also laterally and away from the waste body into the surrounding subsoil. Waste site gas has been detected by the project in distances up to 200 m off the site. This evidence implies that the wall liners of the pit do not provide a completely tight barrier at least against gas migration.

More detailed investigations are planned to analyze the subsoil migration pattern of the gas and to assess its risk potential for the surrounding infrastructure (gas accumulation at explosive levels).

Conclusions

The Thai-German Research Project WADIS puts it focus on the protection of the environment and especially on the protection of groundwater resources

against pollution hazards from waste disposal sites. Abandoned as well as proposed waste sites are equally important to be investigated and assessed with regard to their pollution potential.

The WADIS Project underlines the important role of applied geo-sciences in the safety assessment of waste disposal sites. Safety, control and remediation measures cannot be properly designed without a solid understanding of the geological setting and the hydrology in the subsoil. If these parameters are not taken into consideration, a waste disposal site can remain an "ecological time bomb" with serious threats for the environment and human health.

The WADIS Project demonstrates at selected test sites in an exemplary and comprehensive way how appropriate geo-scientific methods and technologies can be applied in site investigations. The edition of an Investigation Handbook is considered as an encouragement to initiate and guide future site investigations in Thailand. The joint venture character of the project between German and Thai companies as well as governmental institutions enables a close transfer of technical know-how and opens the door for future cooperation.

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