DIPLOMA THESIS

Developing an integrated concept for sewage sludge treatment and disposal from municipal wastewater treatment systems in (peri-) urban areas in Vietnam

Entwicklung eines ganzheitlichen Konzeptes zur Behandlung und Entsorgung von Klärschlamm aus kommunalen Abwasserbehandlungsanlagen in (peri-)urbanen Gebieten Vietnams

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Dresden, July 2011
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## Abbreviations

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<th>Description</th>
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<tbody>
<tr>
<td>AbfKlärV</td>
<td>German Ordinance of Waste Sludge</td>
</tr>
<tr>
<td>ADB</td>
<td>Asian Development Bank</td>
</tr>
<tr>
<td>ATV</td>
<td>German Association for Sewage Techniques</td>
</tr>
<tr>
<td>b.d.l.</td>
<td>Below Detectable Limits</td>
</tr>
<tr>
<td>BMU</td>
<td>German Ministry for Environment</td>
</tr>
<tr>
<td>BOD</td>
<td>Biochemical Oxygen Demand</td>
</tr>
<tr>
<td>COD</td>
<td>Chemical Oxygen Demand</td>
</tr>
<tr>
<td>DAAD</td>
<td>German Academic Exchange Service</td>
</tr>
<tr>
<td>DEWATS</td>
<td>Decentralized Wastewater Treatment System</td>
</tr>
<tr>
<td>DIN</td>
<td>German Institute for Standardisation</td>
</tr>
<tr>
<td>DWA</td>
<td>German Association for Water, Wastewater and Waste</td>
</tr>
<tr>
<td>DWWTP</td>
<td>Decentralized Wastewater Treatment Plant</td>
</tr>
<tr>
<td>GIZ</td>
<td>Deutsche Gesellschaft f. Internationale Zusammenarbeit</td>
</tr>
<tr>
<td>GSO</td>
<td>General Statistical Office Vietnam</td>
</tr>
<tr>
<td>GTZ</td>
<td>German Agency for Technical Cooperation</td>
</tr>
<tr>
<td>Hₜ</td>
<td>Net caloric value</td>
</tr>
<tr>
<td>KrW-/AbfG</td>
<td>German Cycle Economic and Waste Law</td>
</tr>
<tr>
<td>Lol</td>
<td>Loss of Ignition</td>
</tr>
<tr>
<td>Mg</td>
<td>Thousand Kilogram := One Ton</td>
</tr>
<tr>
<td>MoC</td>
<td>Ministry of Construction</td>
</tr>
<tr>
<td>MoNRE</td>
<td>Ministry of Natural Resources and the Environment</td>
</tr>
<tr>
<td>MoST</td>
<td>Ministry of Science and Technology</td>
</tr>
<tr>
<td>PE</td>
<td>Population Equivalent</td>
</tr>
<tr>
<td>PPCs</td>
<td>People’s Committee</td>
</tr>
<tr>
<td>QCVN</td>
<td>National Technical Specifications on the Environment</td>
</tr>
<tr>
<td>SNV</td>
<td>Netherlands Development Organization</td>
</tr>
<tr>
<td>TCVN</td>
<td>Vietnamese Environmental Standards</td>
</tr>
<tr>
<td>TS</td>
<td>Total Solids</td>
</tr>
<tr>
<td>TSS</td>
<td>Total Suspended Solids</td>
</tr>
<tr>
<td>UNICEF</td>
<td>United Nations Children’s Fund</td>
</tr>
<tr>
<td>VN</td>
<td>Vietnam</td>
</tr>
<tr>
<td>WB</td>
<td>World Bank</td>
</tr>
<tr>
<td>WC</td>
<td>Water Content</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
<tr>
<td>WMP</td>
<td>Wastewater and Solid Waste Management in Provincial Centers Program</td>
</tr>
<tr>
<td>WWT</td>
<td>Wastewater Treatment</td>
</tr>
<tr>
<td>WWTP</td>
<td>Wastewater Treatment Plant</td>
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Sewage sludge management turns out to be a vital environmental issue in Vietnam due to the mushroom growth of sludge production in wastewater treatment systems. New constructed wastewater treatment installations, a shortening of the emptying intervals of septic tanks as well as upgraded wastewater facilities aggravate the already problematic sludge management. In fact, Vietnam will be facing huge problems with regard to the handling and disposing of sludge in the years to come - due to the increased sludge amount originating from different sources, e.g. sewage sludge, septicage, industrial sludge, water sludge, hazardous and toxic sludge - as well as sludge emerging from river erosion and sedimentation.

Vietnam’s environmental legal framework is complex and multi-faceted. However, the present paper points out that the environmental laws for sludge management in Vietnam have great potential for improvements. The environmental legislations should be extended progressively to provide a framework for urban sewage sludge management. Furthermore, intensive studying of the current Vietnamese environmental legislation texts came to the result that the number of laws and the number of hierarchical lawyers of the legal system should be minimized and generally optimized and simplified. Legal and regulatory complications, in connection with the implementation of legislation, problems with sewerage charges, treatment costs recoveries, and difficulties with enforcement of legislations, exist at all levels. A lot more legal force is required to enact and to implement these laws. Additionally, institutional problems complicate the current conditions as well.

The present diploma thesis elaborates the current situation of sewage sludge management in Vietnam and is dealing with sludge characteristics from both domestic sewage treatment facilities and septic tanks. In particular, sludge properties and the concentration of toxic pollutants in sludge are defined and compared to levels in Germany. During the research, different treatment components and treatment facilities have been analyzed to carry out a comprehensive survey of sewage sludge types. Unfortunately, scientific information on wastewater sludge for developing countries in Southeast Asia is still meager.

Besides, the research has been focused on treatment facilities of the wastewater program (WMP) and also other additional treatment plants, which have been inspected. During various site visits and in interviews with ministries, decision makers, directors or chairmen of solid waste or wastewater companies, extensive information
ABSTRACT

has been collected and evaluated. Furthermore, current sludge management practices as well as options for treatment and disposal of sewage sludge are reviewed and associated problems are evaluated.

With this experience to build on, an integrated sludge treatment and disposal concept for further sewage sludge management in Vietnam has been developed in the present diploma thesis. Moreover, two sludge treatment concepts are proposed, depending on the respective sludge quantity. The recommended concepts are designed to manage sludge ranging from small-scale to medium- up to large-scale treatment. The chosen technology basically consists of preliminary treatment, thickening, stabilization, dewatering and drying as well as re-use or disposal. These treatment plants will transform sewage sludge in a solids fraction with greatly reduced volume and a very low pathogen content, and in a liquid fraction suitable for discharge after a minimal treatment in a wastewater treatment plant. After a detailed evaluation of all available sewage sludge treatment technologies, specially constructed drying beds have been chosen for both concepts as the preferred option for Vietnam. Conventional drying beds, which are part of the large-scale concept, represent a feasible option for the prevailing condition in Vietnam whereas on the other hand drying beds with reeds, being part of the small-scale concept, operate with a lot less effort in terms of procedure.

However, the options tend to show high performance and are economically well elaborated. Furthermore, the tropical climate in Vietnam is a great advantage for the sludge treatment process as it makes the procedure more efficient. The rainy season is carefully considered in both of the developed concepts. The solids produced from both sewage sludge treatment concepts constitute an excellent organic fertilizer. The mineralized matter and the compost can be utilized as explained in the draft of a guideline.

In this thesis, a guideline (draft) was developed as a main result, which can be helpful to bridge the legislative gap for sewage sludge re-use in Vietnam. Simultaneously, the draft should be understood as an opening of a debate about utilizing pre-treated sewage sludge in selected areas in agriculture. Rather, the commercialization of all these produced biosolids is highly recommended, because it can generate revenues, save landfill space and ensure certain supply of biosolids in selected areas in Vietnam with a very high demand of soil-conditioners.

In summary, as a result of this paper, an integrated concept has been developed, which recommends the application of selected proceeding elements to treat sewage sludge and the further utilization of re-useable materials in agriculture in a controlled and environmentally-safe manner.
1 INTRODUCTION

Water is the essential basis for all forms of life. Urbanization, industrial development as well as extensive agricultural production have a significant impact on the quality and quantity of the resource water. Under the high pressure of population growth, the demographic change and the transformation to a free market economy, Vietnam faces a lot of challenges in various sectors, including wastewater and solid waste management. Especially the augmentation of municipal wastewater and solid wastes in urban areas can be seen as a direct consequence of the rapidly growing urbanization rate. Today, insufficient water supply for urban inhabitants and the lacking coverage of sewage disposal are based on slower developments of urban infrastructures in the municipal areas.

In fact, the capacity of wastewater treatment is still limited. In the majority of cases, untreated wastewater is discharged directly into surface waters and infiltrates the groundwater resource. Today, barely a couple of the major Vietnamese cities have wastewater treatment plants (WWTPs), whereas an estimated 96 percent\(^1\) of the wastewater in Vietnam runs off untreated. Most of the collected municipal wastewater discharges, into rivers, channels or lakes, for instance. Only 4\% of the collected septage (septic tank waste) is treated, [AECOM (2010), p. 115-127]. As a consequence, poorly treated waste (wastewater and solid wastes) leads partly to a potential threat to human health and the environment.

Waste management as well as sludge management depend on different technical, ecological, economical and political aspects which have an impact on environmental activities. In wastewater treatment plants, sewage sludge accumulates during the treatment process and has to be dealt with in an appropriate way to avoid negative impacts on the environmental media and to mitigate the risk of affecting human health. In particular, pathogen reduction is relevant when sludge is disposed of or re-used in a way that human contact is possible. In the sanitation sector, a growing attention for issues of sustainability can be observed. In general, these interests are expressed through, an increasing number of initiatives that are focused on the closing of water and nutrient cycles and the recovery and re-use of these resources. Finally, waste incineration (waste-to-energy-disposal) may be classified as a method to recover energy if the closing of resource cycles is ineffective. In the 21\(^{st}\) century, industrial countries

\(^1\) “Total wastewater generated is estimated at 3 million m\(^3\)/day and total built treatment capacity is 125,000 m\(^3\)/day.” [AECOM (2010), p. 115-127]
INTRODUCTION

indicate an increasing interest in sustainable sludge management, including the production of value-added products from wastewater sludge.

In Western Europe, sewage sludge management and its strategies are implemented but they are authorised according to the respective local conditions. When we want to transfer these Western European technologies and experiences to other countries, a number of factors have to be taken into consideration, including climatic, cultural, social, political and financial conditions. Developing countries do not have much experience with regard to resource recovery from wastewater or sewage sludge management. This is also the case for Vietnam. The situation in Vietnam is very typical for urban areas in developing countries, where on-site sanitation (decentralized systems) principally predominates over sewerage, but where collection and suitable disposal or treatment of sludge is inadequate.

Therefore, this present study is carrying out an applied research to contribute solutions to close this gap. In this respect, it has been very challenging through to give a state of knowledge for a sewage sludge management concept in Vietnam because of misunderstandings in communication, different research conditions, restricted technical possibilities and difficulties to obtain information.

The purpose of this paper is to develop an integrated concept for sewage sludge utilization and disposal from municipal wastewater treatment systems of (peri-)urban areas in Vietnam. Consequently, the present work presents a variety of compacted methods for sewage sludge utilisation and disposal and it can be used as a pragmatic and effective guidebook. The report concentrates mainly on a comprehensive survey of various technologies and methods recently used for sewage sludge management, with major emphasis on municipal wastewater. The second study objective is to clearly outline the legal framework in Vietnam and the theoretical basis for the concept. Presenting a draft of a guideline, summarize and abstract several results of the research and recommend strategies and practices are additional objectives.

The present study addresses the Vietnamese government, different ministries, the municipal authorities, the urban administration, the People’s Committee, owner as well as operation companies of WWTPs and all stakeholders which are connected with the management of sewage sludge including approaches to its re-use and disposal.

The situation of sewage sludge management in Vietnam has been evaluated during various site visits and interviews. Furthermore, sludge samples have been taken and analysed. All the available information and secondary literature have been assessed, too. Moreover, the paper thoroughly explains the Vietnamese legal and institu-
tional framework as well as standards. A comprehensive analysis of grab samples of sewage sludge and wastewater samples has been carried out to verify typical sewage sludge characteristics. Additionally, treatment facilities of the program “Wastewater and Solid Waste Management in Provincial Centres” and also other additional treatment plants have been focused on and inspected. Based on lessons learned, the report gives a detailed abstract such as a retro-perspective view on past projects, demonstrates the current situation and should provide preventive indications to avoid mistakes and risks. In detail, the paper consists of the following main parts:

Part 1: Legal framework of sludge management in Vietnam,
Part 2: Theoretical basis for the concept,
Part 3: WWM Program information, analysis and learned outcomes,
Part 4: Sewage sludge management concept and a draft of a guideline,
Part 5: Summary and further prospects.

The study took place in Vietnam at Hanoi University of Science in the framework of the DAAD (German Academic Exchange Service) – “An advancement of the German-Vietnamese University partnerships”. The research has been supported by the program: “Wastewater and Solid Waste Management in Provincial Centers” and belongs to its technical part (chapter 4.2).

In order to give suggestions to improve the recent situation in Vietnam, this paper gives an overview of the latest knowledge of sewage sludge treatment, re-use as well as disposal in (peri-)urban areas in Vietnam. Inevitably, due to the vast topic area, this diploma thesis makes no claim to be complete. Furthermore, all chapters are equally important regardless of their relative quantity of information.

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2 Mastercourse Waste Management and Contaminated Site Treatment TU Dresden – Hanoi University of Science
2 LEGAL FRAMEWORK FOR SEWAGE SLUDGE MANAGEMENT IN VIETNAM

2.1 BACKGROUND

The chapter presented here is the first of its kind dealing with the legal framework for sewage sludge management in Vietnam and thoroughly explains the legislations, legal and institutional framework as well as standards. The legal framework of the water sector in Vietnam is abstract, complex and in state of a continuous change. [NGUYEN THI PHUONG (2010a), p. 1-7] Since 1986, the aspect of environmental protection has become more significant in the constitutional level in Vietnam. This can be observed in the articles 17 and 29 of the 1992 Vietnamese Constitution. The first Law of Environmental Protection was enacted by the National Assembly in 1993. The foundation for the Law on Water Resources (No. 08/1998/QH10) was established in 1999 and describes the framework for managing the water sector in Vietnam. Subsequently, environmental legislations have been advanced. [NGUYEN THI PHUONG (2010a), p. iii] All legal documents belong to a clearly arranged hierarchy from high to low legal force. The legal system consists of more than 20 types of legal documents enacted by different state bodies. [NGUYEN THI PHUONG (2010a), p. 10-13] Due to its complexity, many confusions occurred when having implemented the legal documents, [NGUYEN THI PHUONG (2010a), p. 11]. Significantly, Vietnam’s legal documents are structured into Decisions, Circulars, Resolutions and Joint resolutions.

2.2 INSTITUTIONAL FRAMEWORK

A lack of clarity and a usually inappropriate division of responsibility between ministries and institutions generally leads to considerable delays in the preparation, approval and implementation of almost every project. Similarly, weak points in internal organisation, an insufficient number of staff and inadequate qualifications of staff at all institutional levels negatively affect project processes (implementation, effectiveness and sustainability). [INWENT (2009), p. 111] Moreover, many institutional bodies overlap each other when it comes to competences and actions, for example MoC and MoNRE in Vietnam’s water sector, [NGUYEN THI PHUONG (2010a), p. 132-137]. The local wastewater or solid waste companies (all urban environmental enterprises) have been pooled in limited liability companies. However, the financial management is under total control and supervision of the governmental institutions. The government distrib-
utes budgets for the urban environmental issues, but the provided budgets are not sufficient enough to cover the running expenses, e.g. operation and maintenance of wastewater treatment systems. Not to mention the fields of facility investments, reinvestments in the system development, or ordered residue management of WWTPs (e.g. sewage sludge). [INWENT (2009), p. 111-113] The institutional system interacts as depicted in (Figure 2-1) below.

![Institutional framework of wastewater management in Vietnam](image)

**Figure 2-1:** Institutional framework of wastewater management in Vietnam [Bisa, B. (2011), p. 6]

The next Table 2-1 presents functions of institutions in the wastewater sector. Local wastewater and urban environmental companies need more capacity and independence to provide services and operate economically. Moreover, these wastewater enterprises call for more knowledge and support for operation, maintenances and financial management. At local levels, technical and management capacities are low-developed and in combination with the newly introduced and often "foreign" wastewater technologies, the local authorities are facing many problems. [INWENT (2009), p. 111-113] In many cases, management of sewage sludge provided by provincial urban environmental companies in Vietnam is considered to be inadequate and incomplete.

**Table 2-1:** Functions of institutions [HYDROCONSEIL/PEM Consult (2011), p. 15]

<table>
<thead>
<tr>
<th>Function</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy-setting</td>
<td>Ministry of Construction (MoC)</td>
</tr>
<tr>
<td>Planning and financing</td>
<td>Ministry of Planning and Investment (MPI) and Ministry of Finance (MoF)</td>
</tr>
<tr>
<td>Operation and Maintenance</td>
<td>Provincial Urban Environmental Companies (URENCOs), controlled by the PPCs</td>
</tr>
<tr>
<td>Monitoring and Evaluation</td>
<td>Ministry of Health (MoH) regulates the quality of water supply and sanitation and the Ministry of Natural Resources and Environment (MoNRE) the quality of effluents.</td>
</tr>
</tbody>
</table>
LEGAL FRAMEWORK FOR SEWAGE SLUDGE MANAGEMENT IN VIETNAM

To improve the current situation, the institutional framework should be researched in a better way because the institutional landscape is not completely clear at the moment. This analysis should deal with roles, responsibilities, gaps and overlaps of the institutional organs in Vietnam. Based on the research results, the institutional framework should be modified and changed. An introduction of sewerage charges at public levels in Vietnam is necessary. In this respect, the local governments have to raise awareness for wastewater cleaning services at public levels. The services provide high benefits for public health. Moreover, trainings and capacity building are required at local levels, which focus on management, operation and maintenance of the existing wastewater infrastructure (in practice). [INWENT (2009), p. 111-113]

2.3 LEGAL FRAMEWORK

Environmental laws and regulations in Vietnam are relatively well-developed. There is a set of Laws, Decrees and Circulars given which covers almost the whole territory in terms of sludge management. [INWENT (2009), p. 87] These include:

1. Law on Environmental Protection promulgated on November 29, 2005, came into force on July 1, 2006;
2. Law on Water Resources 1998;
3. Government Decree 80/2006/ND-CP, August 9, 2006, detailing the implementation of Law on Environmental Protection;
4. Circular 08/2006/TT-BTNMT, September 8, 2006, providing instruction and guidance on strategic environmental assessment (SEA), environmental impact assessment (EIA) and environmental protection engagement;
5. National Strategy on Environmental Protection up to the year 2010 and Vision to 2020, approved by Decision No. 256/2003/QD-TTg, issued on December 2, 2003 by the Prime Minister;
6. Strategic Orientation for Sustainable Development (Viet Nam Agenda 21), approved by Decision No. 153/2004/QD-TTg, issued on August 17, 2004 by the Prime Minister;
MoNRE has enacted Circular 08 to supply “(...) detailed instructions of strategic environmental assessment, environmental impact assessment and other environmental enforcement tools”, [INWENT (2009), p. 87]. Thereby, the two first environmental enforcement tools play a major role for the environmental planning and management.

Environmental protection in Vietnam is based on the 2005 Law on Protection of the Environment (No. 52-2005-QH11) which is divided into 15 chapters and 136 articles. In Article 1 of [No. 52-2005-QH11], the Government defines that “This Law regulates environmental protection activities, policies, measures and resources for protection of the environment; and the rights and obligations of organizations, family households and individuals with respect to protection of the environment.”

Principally, the law demands environmentally responsible behaviour from consumers and producers and involves regional and global issues such as climatic change. The regulatory gives a line of general principles: The objective of sustainable development, prevention, the polluter pays principle, the promotion of environmentally friendly technologies and consumer behaviour are formulated. In detail, it firmly enunciates principles of prevention, which are classified into three levels of environmental assessments.

A “list of projects” shows 102 industrial or commercial branches which are all required to have a significant environmental impact. These projects range from telecommunications to power generation, textile, electronics or coffee processing. [UNITED NATIONS (2009), p 72-74] All companies affected by the list of projects have to prepare an “environmental impact assessment report”, [DECREE 80-2006-ND-CP-Appendix].

Chapter VIII describes the general provision of waste management- the 3R’s “(...) reducing, recycling and reusing wastes so as to minimize the quantity of waste to be incinerated or discarded.” and is subdivided into 5 sections, [No. 52-2005-QH11].

In section 4, MANAGEMENT OF WASTE WATER, Article 81 (Collection and treatment of wastewater), is stated that: wastewater produced by urban centers and residential areas must have “(...) separate systems for collection of rainwater and waste water; waste water from daily life must be treated up to environmental standards before being discharged into the environment” and wastewater produced by industry zones, business and service establishments “(...) must be collected and treated up to environmental standards.”
“Mud” [Article 81; Clause 3]\(^3\), considered as sewage sludge that is supposed to be “(...) discharged from waste water treatment systems must be managed according to solid waste management regulations”, [ANH, H. (2009)].

As per clause 4\(^4\), “waste water and mud containing hazardous elements must be managed according to hazardous waste management regulations.” Subsequently, there is stated that “waste management shall be performed under the provisions of this Law and other relevant laws.” [No. 52-2005-QH11]

Furthermore, the Law on Environmental Protection No. 52-2005-QH11 gives attention to the financial aspects of waste and wastewater treatment by setting an “environment fee”. The fee must be paid by projects that exert an “adverse” impact on the environment or by projects that discharge waste into the environment, [UNITED NATIONS (2009), p 72-74].

In detail, wastewater and waste management are particularly formulated in Decree 88 (Urban and Industrial Wastewater Management) and Decree 59 (Solid Waste Management), [INWENT (2009), p. 88]. Decree No. 59/2007/ND-CP aims to provide “solid waste management rights and obligations of entities engaged in solid waste activities”, such as separation, collection, storage, transportation and disposal of solid waste including expenses for solid waste management, inspection, examination and handling of violations, [Article 1]. It also regulates that “polluters pay” a fee for collecting, transporting and treating solid waste, [DECREE No. 59/2007/ND-CP].

Waste management, as defined in Decree 59, Article 3, Clause 1; “(...) means activities of planning, managing, investing in building solid waste management facilities, separating, collecting, storing, transporting, reusing, recycling and disposing of solid waste in order to prevent and minimize adverse impacts on the environment and human health.”

Despite the reference in Article 81; Clause 3, No. 52-2005-QH11, regulations of the management of sewage sludge is not mentioned in Decree 59. In terms of financing sewage sludge management, the Governmental Decree 88 on Wastewater Management introduces an external user fee for wastewater which is different from the environment fee, [INWENT (2009), p. 88]. In case of breaches of environmental protection rules, there are strict penalties and fines according to the law: “Offenders are required to clean up, rehabilitate and pay compensation for losses incurred by third par-

\(^3\) “Bùn thải từ hệ thống xử lý nước thải được quản lý theo quy định về quản lý chất thải rắn”.

\(^4\) “Nước thải, bùn thải có yếu tố nguy hại phải được quản lý theo quy định về chất thải nguy hại.”
ties.” The organization heads can be prosecuted for serious environmental damages. [UNITED NATIONS (2009), p 72-74]

At local levels, Departments of Natural Resources and Environment (Do-NRE's) are qualified organizations under the People’s Committee, which “assist the People’s Committee to implement their state management tasks on natural resources and the environment” and observe the environmental protection, [NGUYEN THI PHUONG (2010a), p. 88].

2.4 STANDARDS

2.4.1 Technical standards

The MoNRE “(...) is responsible for setting and announcing water resource standards and formulating and promulgating technical regulations on the protection and use of water resources”, [NGUYEN THI PHUONG (2010a), p. 55]. Vietnamese Environmental Standards (TCVN) are “compulsory” as regulated by Decision No. 35/2002/QD-BKHCNMT, [NGUYEN THI PHUONG (2010a), p. 55]. A selected overview on TCVNs which belong to wastewater, solid waste as well as sewage sludge management is represented below:

- **TCVN 5945:2005** “Industrial waste water – Discharge standards”
- **TCVN 5942:1995** “Water quality - Surface water quality standard”
- **TCVN 6773:2000** “Water quality - Water quality guidelines for irrigation”
- **TCVN 5941:1995** “Soil quality - Maximum allowable limits of pesticide residues in the soil”
- **TCXDVN 261:2001** “Landfill - Design standard”
- **TCVN 7733:2007** “Water quality - Effluent standards for leachate of solid waste landfill sites”
- **TCVN 6696:2000** “Solid wastes - Sanitary landfills. General requirements to environmental protection”
• TCVN 5298:1995 “General requirements for the use of waste waters and their sludge for watering and fertilizing purposes”
• TCVN 6226:1996 “Water quality - Test for inhibition of oxygen consumption through activated sludge”
• TCVN 6826:2009 “Water quality - Determination of the elimination and biodegradability of organic compounds in an aqueous medium. Activated sludge simulation test”
• TCVN 6705:2000 “Non-hazardous solid wastes - Classification”
• TCVN 6706:2000 “Hazardous wastes - Classification”
• TCVN 7241:2003 until TCVN 7246:2003 “Health care solid waste incinerators - Determination method of different pollutants concentration in fluegas”
• TCVN 7380:2004 “Health care solid waste incinerators - Technical requirements”

2.4.2 National standards

In the years to come, all TCVNs will be transformed into National Technical Specifications on the Environment (QCVN). The process has started 2008.

• QCVN 14:2008/BTNMT “National technical regulation on domestic wastewater”
• QCVN 08:2008/BTNMT “National technical regulation on surface water”
• QCVN 02:2008/BTNMT “National technical regulation on the emission of health care solid waste incinerators”
• QCVN 03:2008/BTNMT “National technical regulation on the allowable limits of heavy metals in the soils”
• QCVN 02:2009/BYT “National technical regulation on domestic water quality”
• QCVN 01:2009/BYT “National technical regulation on drinking water quality”
2.5 CURRENT SITUATION

As in many developing and transformation countries, also in Vietnam legislations, regulations and standards are not completely followed and fulfilled. In practice, the implementation of laws and provisions is based upon time, place, technical conditions, state observation, financial potential etc. Especially export-orientated industrial companies begin to meet the regulatory requirements because an ecologically sensitive production can be more attractive for consumers (merchandising), e.g. ISO- and EMAS-certificates. Other industrial enterprises, state owned wastewater companies, local authorities and agriculture enterprises have to operate with their available capital. This financial budget is still very limited in Vietnam. [CORNEL, P. et al. (2005), p. 392]

By now, Vietnam’s legislation is constructed as a complex system of legal and regulatory documents which are enacted by different state agencies. Due to its complexity and the diversity of laws, the complicated implementation processes turn out to be insufficient at provincial and communal level. [NGUYEN THI PHUONG (2010a), p. 5] Owing to the pressure of industrialisation, the water resources have not been protected in an appropriate manner. The fact that the Vietnamese legal system is generally complex causes complications with overlapping and contradictory regulations. Obviously, present regulations should be checked, systemised and justified. At the same time, unjustified, overlapping and contradictory legal documents must be revised. [NGUYEN THI PHUONG (2010a), p. 132-137]

The following key points provide helpful suggestions which should improve the legal and regulatory situation in Vietnam: [LEARY et al. (2010), p. 247-269]

1. “Education and training” - Many developing countries have a lack of well-skilled officials with sufficient knowledge of wastewater treatment and solid waste management. Moreover, marketing to permit successful project implementations is required.

2. “Public involvements and transparency” - The environmental awareness of individuals, officials, organizations, state-owned companies, enterprises or others are indicated as very inadequate.

3. “Legal framework” - The necessary legal system is mostly incapable of governing contractual agreements, regulating sustainability and environmental or social aspects. Clearly arranged regulations for sanitation and sanitation services have to be enacted to achieve improved sanitation infrastructure, service efficiency and quality in the future. Hygienic and environmental awareness are increasingly required.
Furthermore, it is necessary to develop a handling and managing concept for sewage sludge and septage in urban as well as rural areas in Vietnam.

4. “Enforcements/ Corruption” - As OTTINGER, L. R. stated in [LEARY et al. (2010), p. 250] “The required enforcement structure is not always in place, with appropriate penalties for violations and sufficient numbers of adequately paid and trained personnel to ensure that laws are complied with.” At least annually, regular inspections and publications of reports on the observance of relevant laws and regulations are necessary.
3 THEORETICAL BASIS FOR THE CONCEPT

Management of sewage sludge is part of the modified anthropogenic water cycle. The water quality of natural water circulation is modified by exploitation, conditioning and consumption as well as disposal. An organisation of sludge management should take into consideration the entire process chain of water quality including interactive parameters. Therefore, as an overview, the water cycle in general, the drinking water abstraction, drinking water purification and drinking water distribution as well as wastewater collection and wastewater treatment are presented in Figure 3-1. [THOMÉ-KOZMIENSKY (1998), p. 3-20]

![Figure 3-1: Structure of water-wastewater-cycle](image)

The major sources of water pollution in developing countries are based on domestic, industrial and agricultural impacts. Wastewater strategies should concentrate on this range of indicators: [ULRICH, A. et al. (2009), p. 21]

- Wastewater (human excreta, urine, faeces := black water)
- Household wastewater (wash water, shower water := grey water)
- Storm water
- Waste from industrial production
- Hazardous waste (as from hospitals)
- Solid wastes (such as sewage sludge)
3.1 SEWAGE SLUDGE

Sewage sludge is the mixed residue out of water and solids which has been accumulated during the water treatment process of industrial and municipal wastewater. In prior to its utilisation or disposal, sludge requires further treatment to reduce epidemiological pathogens and organic content. The total amount generated depends “(…) on the number of households, the number of industrial plants and the efficiency of the sewage treatment plants”, [BILITEWSKI (2000), p. 42].

As illustrated in Table 3-1, approximately two million tons (Mg) of sewage sludge from around ten thousand biological municipal purification plants were disposed of in 2008 (Germany).

Table 3-1: Statistical data of water management in Vietnam and Germany

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of sewage treatment plants</th>
<th>Sewage connection rate [%]</th>
<th>Wastewater volume [million m³]</th>
<th>Sewage sludge [million Mg dry matter]</th>
<th>Federation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>9,933</td>
<td>96</td>
<td>10,071</td>
<td>2.05</td>
<td>Germany⁵</td>
</tr>
<tr>
<td>2008</td>
<td>n.a.</td>
<td>~65</td>
<td>n.a.</td>
<td>n.a.</td>
<td>Vietnam⁶</td>
</tr>
</tbody>
</table>

Compared to Germany, Vietnam still has an immense backlog in terms of sewerage connection rate (Table 3-1). The paper of AECOM (2010), p. 115-127 reported that 65% of the inhabitants in Vietnam have access to sanitation at the national level (rough estimates), calculated with the urban (88%) and rural sanitation access (56%) and the population distribution (urban/rural). In this case, it should be tried to question the correctness of the sewer connection rate data. Other findings of [RASCHID-SALLY (2004), p. 1],“(…) indicate that 75% of domestic wastewater in large cities and 45% in smaller cities are discharged into sewers.” and illustrate even lower values for the cities. Only a few major cities in Vietnam have WWTPs of which only a few can be operated. The bulk of the collected wastewater is discharged untreated (Table 3-2). No sta-

⁵ Source: Federal Statistical Office (Destatis), Data based on German Ministry of the Environment (2008)
⁶ Source: [AECOM (2010), p. 115-127]
tistics have been found when it comes to the actual volume of sludge in Vietnam. The data of the total amount of sludge in Vietnam is not available at the moment because the WWTPs are restricted in terms of operation and maintenance. The following Table 3-2 illustrates that more than three quarters of urban households in Vietnam depollute wastewater within septic tanks. [AECOM (2010), p. 115-127] State-run as well as private septic companies generally collect faecal sludge with vacuum tankers and transport the sludge to existing septic treatment plants or landfill sites, if applicable, while more common methods tend to “dispose of septage in drains, fish farms, and waterways”, [AECOM (2010), p. 119]. These practices of disposal violate the Vietnamese law [TCVN 5945-2005] and are illegal. It is forbidden to dump septage into the environment, in drainages as well as irrigation channels and in fishponds. [KLINGEL (2001), p. 4-10]

Table 3-2: General statistical data (Vietnam) [AECOM (2010), p. 115-127]

| Total population (in millions) 2010 | 87 | Nominal GDP (in billion $) 2010\(^7\) | 101.5 |
| Urban population (in millions) | 23 | Nominal income ($ 2010) | 1.200 |
| Urban population (in % of total) | 27 | Annual water budget per cap | - |
| Access to improved water (in %) | 98 | Annual sanitation budget per cap | - |
| Access to improved sanitation (in %) | 88 | Fee to desludge (in $ per m\(^3\)) | 9-13 |
| Access to piped sewerage (in %) | - | Polluted surface water bodies | - |
| Use of septic tanks (in %) | 77 | Economic cost for poor sanitation (in million $) | 780 |
| Treatment of Collected Sewage (in %) | 4 | |

However, typical appliances for untreated wastewater and sewage sludge have been utilised in agriculture, aquaculture (fishponds) and landscaping measures inducing immense health risks, [NGUYEN VIET ANH (2010), p. 17]. In 2010, with an average income of 1.200 $ in Vietnam (Table 3-2), desludging a septic tank is still cost-intensive for many households, especially if the invoice amount has to be paid all at one, [AECOM (2010), p. 115-127]. Companies which operate and maintain wastewater treatment plants are facing the same problems. The Governmental Degree 67 and 88, aim to charge a wastewater fee. As reported in the paper [AECOM (2010), p. 115-127], “(...) specifically, the public service companies are responsible for collecting a 10 percent fee on all water bills.” Currently, there cannot be observed a lot of willingness neither to pay water supply fees nor wastewater fees in Vietnam, [VIETNAM NEWS (11/02/2011)]. As a consequence of this, wastewater discharges without significant treatment into the water cycle, for example, into the soil and into surface water (lakes,
rivers, coastal water and channels) and therefore infiltrates the groundwater, [AECOM (2010), p. 115-127]. When wastewater comes into contact with nature and natural resources, natural degradation processes start simultaneously. Due to these impacts, contaminated particles (inorganic and organic compounds) start to settle and concentrate on the benthic division. As a representative example, for this known problem, lake Hoan Kiem (Table 4-1) can be cited. In Vietnam there are numerous examples for this issue.

VIETNAM NEWS (09/03/2011) reported that they have started to dredge and clean the beds of “(...) city’s lakes and rivers all severely polluted because of uncontrolled urbanisation and industrialisation (...)”, and especially “(...) four rivers with their channel network have been highly polluted for years, creating visual pollution and strong smells.” Moreover, “(...) a report by the city Environment and Natural Resource Department last year found that BOD$_5$ (...) in the Tô Lich River was 7.13 times above the accepted level, 2.84 times in the Sét River and 5.28 times above in the Lù River”, [VIETNAM NEWS (09/03/2011)].

As reported by the Federal Statistical Office [Destatis (22/12/2009)], more than half (52.5%) of the nearly two million tons (Mg) of sewage sludge from municipal purification plants was incinerated in 2008. In Table 3-3, a variety of contributions for utilisation and disposal of waste sludge from biological wastewater treatment in Germany have been exemplified.

**Table 3-3: Disposal of waste sludge from biological wastewater treatment [DESTATIS (2008)]**

<table>
<thead>
<tr>
<th>direct disposal of waste sludge total [Mg]</th>
<th>in agriculture$^8$ [Mg]</th>
<th>in landscaping measures$^9$ [Mg]</th>
<th>other material recycling [Mg]</th>
<th>thermal waste disposal [Mg]</th>
<th>landfill$^{10}$ [Mg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 054 102</td>
<td>587 832</td>
<td>331 556</td>
<td>54 609</td>
<td>1 077 624</td>
<td>2 481</td>
</tr>
</tbody>
</table>

Direct dumping on landfill sites has been reduced to less than 1 % of the whole waste sludge accumulation (Figure 3-2). Slightly more than a quarter has been used in agriculture. Exactly 16.1 percent have been used for landscaping measures in Germany. The entire allocation of disposal of waste sludge in percentage is clearly presented in Figure 3-2.

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$^8$ According to German ordinance of waste sludge (Klärsschlammmverordnung - AbfKlärV)

$^9$ For example composting and recultivation

$^{10}$ If allowed according to German ordinance of waste disposal (Abfallablagenungsverordnung - AbfAblV).
The general statistic office of Vietnam (GSO) has published a few clauses about environmental protection in the report on “SOCIO-ECONOMIC STATISTICS, 2010”. Among the statistics it is stated that, "(...) liquid wastes generated from businesses in 2008 were 412 million m³ of which 82.4% of the wastes were treated”, [GSO (2011)].

In brief, Vietnam’s current sludge disposal possibilities have caused many complications concerning the disposal of existing and newly generated amounts of waste sludge. The discharge of untreated domestic waste sludge into channels and rivers, as well as inappropriate disposal of partially treated waste sludge, lead to potential risks for public health and the environment to a large extent. The problem is portrayed, for example in an article of [VIETNAM NEWS (15/04/2011)], whereby about 900 m³ of sludge has been dumped into the sea of Vũng Tàu. The sludge was dredged from the city’s Dinh river. At the same time, the responsible wastewater company in Can Tho city has reported in an interview [WSSC CAN THO, Head of Waste Water Department, Ms Tien], that the company has stopped the dredge campaign because of restricted sludge treatment and disposal paths. The most common disposal path for untreated sludge still is the direct discharge into landfills. For instance, the landfill statistics of 2010 in Kieu Ky (Gia Lam) have shown that 42 Mg untreated waste sludge per day have been disposed of, [FRANCES, A. (2011)]. Landfill sites in Vietnam are “running short” of the capacities in the future, as reported by [VIETNAM NEWS (04/04/2011)]. In this case, the increase of waste and a lack of waste treatment or recycling possibilities lead to a growth of this kind of waste disposal. Furthermore, “up to 85-90% of the dumps in use had failed to meet sanitation standards, posing high health and environmental risk”, as stated in the report. Besides, to solve the problem, Vietnam “(...) had invested in upgrading and expanding dumps and the waste treatment plants, seeking to improve their capacity and use more modern technology to protect the environment.” Vietnam’s land resources will become more and more limited and landfill sites are just temporary measures. Alternative measures to ecological harmful waste disposal are urgently needed. [VIETNAM NEWS (04/04/2011)] Due to the rising prices of
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fertilizers, sewage sludge and its controlled re-use in agriculture should be taken into consideration. The countries demand of 8.5 million Mg of fertilizer currently cannot be covered by the own production of fertilizer (5.9 million Mg). [VIETNAM NEWS (09/05/2011)] Immediate action is required to modify the ways sewage sludge is disposed of and corresponding legislation.

3.1.1 Sewage sludge types

In general, wastewater and household wastewater are treated in municipal WWTPs. Sewage sludge is basically composed of water and organic and inorganic solids. In principle, the generated sewage sludge varies in its quality and quantity according to regional wastewater characteristics and used wastewater treatment technology. Between and after each wastewater treatment step (Figure 3-3), sludge is accumulated. [THOMÉ-KOZMIENSKY (1998), p. 57]

![Figure 3-3: Wastewater treatment process](image)

In typical wastewater treatment plants, sewage sludge is produced according to the process scheme in Figure 3-3. The figure explains the three basic steps of wastewater treatment, which are mechanical, biological and chemical treatment. Main sludge types are defined in DIN-EN 4045 and DIN-EN 1085 according to their appearance. The norms differentiate sewage sludge into primary, secondary and tertiary sewage sludge as well as screenings, grit and scum (grease, fat, oil and floating sludge). Sludge, according to [DIN-EN 1085 (1997), nr. 1020] is a generic term for a, “mixture of water and solids separated from various types of wastewater as a result of natural or
artificial processes.” with reservations that “the residues of preliminary treatment are not considered as sludge.”

In Table 3-4 below, the different definitions of sludge are presented in a comprehensive summing-up. Essential for this study is municipal sludge in (peri-)urban areas, for instance septage and sewage sludge, which have been accumulated in decentralized wastewater treatment plants. Typical on-site facilities for sludge are pit latrines, septic tanks, decentralized wastewater treatment plants and grease traps. [SCHMIDT, A. (2010), p. 2] Industrial sludge is listed in Table 3-4 but is not subject matter of this research.

Table 3-4: Overview of sludge types [THOMÉ-KOZMIENSKY (1998), p. 107-113]

<table>
<thead>
<tr>
<th>Sludge type</th>
<th>Definition (according to [DIN-EN 4045] and [DIN-EN 1085])</th>
</tr>
</thead>
<tbody>
<tr>
<td>raw sludge</td>
<td>non-stabilised sludge</td>
</tr>
<tr>
<td>primary sludge</td>
<td>sludge removed from primary treatment, unmixed with other recycled sludge</td>
</tr>
<tr>
<td>secondary sludge</td>
<td>sludge separated after secondary or biological treatment</td>
</tr>
<tr>
<td>precipitation sludge/chemical sludge</td>
<td>sludge separated after chemical precipitation or flocculation</td>
</tr>
<tr>
<td>stabilised sludge</td>
<td>sludge which has been subjected to a stabilisation process, thereby reducing its tendency to degrade below a specified level</td>
</tr>
<tr>
<td>anaerobically digested sludge</td>
<td>sludge stabilised by anaerobic digestion</td>
</tr>
<tr>
<td>aerobically digested sludge</td>
<td>sludge stabilised by aerobic digestion</td>
</tr>
<tr>
<td>septage</td>
<td>sludge removed from septic tanks</td>
</tr>
<tr>
<td>sludge liquor</td>
<td>liquor separated from sludge (note: sludge liquor can be called: supernatant (thickener, digester), decantate (decanter), filtrate (filter), centrate (centrifuge))</td>
</tr>
<tr>
<td>thickened sludge</td>
<td>separated sludge from heterogenic mixtures with higher solid concentration (note: solid content 20-40 %)</td>
</tr>
<tr>
<td>thin sludge</td>
<td>fresh concentrated sludge or anaerobically digested sludge (note: solid content until 20%)</td>
</tr>
<tr>
<td>industrial sludge</td>
<td>sludge removed from industrial production process, multi-mixed chemical sludge substances</td>
</tr>
</tbody>
</table>

Besides sludge, grit, grease and screenings are separated in the wastewater treatment process (Figure 3-3). These residues are not characterised as sludge, but as solid wastes. Grease can be used additionally for the biological stabilisation processes or anaerobic digestion of sludge, as illustrated in Figure 3-5. Grit and screening are utilised as solid wastes. After dewatering screenings and grit, they can be treated like
solid waste. According to Figure 3-4 treatment rests can be disposed of on landfills. After washing grit, it can be re-used in road construction; otherwise it can be dumped in landfill sites. Another possibility therefore is to use it for cover layers in those landfills, as shown in Figure 3-4. [THOMÉ-KOZMIENSKY (1998), p. 57-62]

![Figure 3-4: Treatment and utilisation possibilities for grit](image)

In the beginning of each waste utilisation organisation basic material characteristics as well as the actual situation and a prognosis of the to be produced residues (quantity of waste) should be determined, [BILITEWSKI (1996)].

![Figure 3-5: Treatment and utilisation possibilities for screenings](image)
### 3.1.2 Quantity

First of all, as a precondition, it is important to know about the total amount of produced sludge for further applications. The exact quantity is taken as a basis for the dimension of the design capacity, treatment capacity and logistical organisation. With each treatment step more sludge accumulates. According to requirements the total amount of sludge can be estimated based on empirical values. The example given in Table 3-5 shows typical values by Imhoff. [THOMÉ-KOZMIENSKY (1998), p. 107-133]

### 3.1.3 Sludge volume

Sewage sludge is a voluminous residue of municipal wastewater treatment. The water content has a major influence on the sludge volume. [KÜHN, V. (2008), p. 9-13] Reducing the volume immensely decreases the costs for transport and storage, [INVENT (2009), p116]. All in all, transport is the main cost factor, [SCHMIDT, A. (2010), p. 4]. While the solid matter in the example below is constantly at 25 m³, the change of volume due to dewatering can be observed in Figure 3-6. The volume can be significantly reduced down to a solid content of 35%. Afterwards, volume reduction is limited and significant minimization can be obtained. [KÜHN, V. (2008), p. 16]

![Figure 3-6: Sludge volume reduction][107-133]

By means of sludge digestion, the organic component can be minimized down to 50%, as represented in Figure 3-7. As a result, the total solid content decreases to
62.5%. The produced biogas can be used to cover the energy costs for the wastewater and sludge treatment process. [DICHTL, N. (2011), p. 10]

3.1.3.1 Municipal sludge

Urbanisation and the population growth result in an increasing number of WWTPs and a growing amount of sewage sludge that has to be treated and disposed of. With the increase of environmental problems resulting from a lack of treatment and disposal facilities, the necessity to act is getting more and more obligatory. Obtaining information about sludge production rates is the starting point for successful sludge management design, which becomes a high priority task for engineers. [L’HERMITE, P. (1991), p. 14-44]

In Vietnam, there is no reliable reasonable information about sludge production rates from different wastewater treatment processes. Available values have to be adjusted to other empirical values (Table 3-5) to calculate an expected amount of sewage sludge. The total amount of sludge without industrial activity can be ascertained through the total number of people living in households connected to the WWTP. Daily incidental sludge quantity and quality by [THOMÉ-KOZMIENSKY (1998), p. 107-133] depends on:

- Living standards, lifestyle (consumption of water and alimentation),
- Climatic situation,
- Place of employment,
- Connection to a sewer (inside or outside the catchment area of the WWTP),
- Used technical standards and the WWT technologies and prevailing conditions of operation.
As detail given below in Table 3-5, the conventional values according to Imhoff are outlined. Hence, the table illustrates general sludge production rates in different WWT steps.

Table 3-5: Suspended solids and sludge volume according to WWT steps [IMHOFF, K. R. (1983)]

<table>
<thead>
<tr>
<th>Raw sludge of the settlement tank</th>
<th>Solids [g/(cap·d)]</th>
<th>Loss of ignition [%]</th>
<th>Total solid content [TS %]</th>
<th>Sludge production [l/(cap·d)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary sludge</td>
<td>54</td>
<td>38</td>
<td>5-10</td>
<td>0.72</td>
</tr>
<tr>
<td>Biological filter sludge from the clarifier</td>
<td>10-20</td>
<td>6-10</td>
<td>4-8</td>
<td>0.25</td>
</tr>
<tr>
<td>Surplus activated sludge from the clarifier biological step</td>
<td>20-30</td>
<td>15-23</td>
<td>0.5-2.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Anaerobically digested sludge, distance from the digester</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary sludge</td>
<td>34</td>
<td>17</td>
<td>5-12</td>
<td>0.4</td>
</tr>
<tr>
<td>Primary sludge and biological filter sludge</td>
<td>40-43</td>
<td>20-24</td>
<td>5-10</td>
<td>0.6</td>
</tr>
<tr>
<td>Primary sludge and surplus activated sludge</td>
<td>48-60</td>
<td>24-30</td>
<td>4-8</td>
<td>0.9</td>
</tr>
</tbody>
</table>

The population equivalent is defined in [DIN-EN 1085 (1997), No. 1040]:

“Conversion value derived from comparison of trade wastewater or industrial wastewater with domestic wastewater as determined from the daily quantity of wastewater or sewage substances.

- **Population equivalent based on BOD$_5$, eg PE$_{B60}$** means that the population equivalent is based on five days biological oxygen demand of the wastewater, amounting to 60 g/(cap·d). Note: This is a definition of population equivalent defined in urban wastewater directive EEC. Alternative means of defining population equivalents given below.

- **Population equivalent based on daily amount wastewater per inhabitant, eg PE$_{W200}$** means that the population equivalent is based on an amount of wastewater of 200 l/(cap·d).

- **Population equivalent based on suspended solids, eg PE$_{SS70}$** means that the population equivalent is based on a wastewater suspended solids amount of 70 g/(cap·d).
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- Population equivalent based on Kjeldahl nitrogen (KN) means that the population equivalent is based on Kjeldahl nitrogen of the wastewater amounting to 12 g/(cap·d).
- Population equivalent based on P, or PE\textsubscript{P2} means that the population equivalent is based on total phosphorous of the wastewater amounting to 2 g/(cap·d).

The daily incidental sludge volume of a WWTP amounts to 2 l/(cap·d) and accumulates a solid content of 80 g/(cap·d). The major parameter for dimension the design capacity and treatment capacity depends on the total number of inhabitants and the population equivalent. The total population (PT) is defined as the sum of population and population equivalent: \( PT = P + PE \) [THOMÉ-KOZMIENSKY (1998), p. 107-133]

3.1.3.2 Total sludge amount in Vietnam

A calculation or an estimate calculation of the total amount of sewage sludge in Vietnam has been outlined in the well-arranged overview in Appendix A. The calculation shows the produced total dry solid mass of sludge with the assumption that only activated sludge treatment processes are used. Approximately 2.5 million Mg dry solid matter of sewage sludge is estimated to be produced when all households are connected (Table 3-6). Sludge is only accumulated in WWTP’s when the wastewater is collected through sewer systems and treated afterwards.

Table 3-6: Sludge amount depending on house connection [Appendix A]

<table>
<thead>
<tr>
<th>House connection [%]</th>
<th>100</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produced amount million [Mg dry TS per year]</td>
<td>2.54</td>
<td>2.03</td>
<td>1.77</td>
<td>1.52</td>
<td>1.27</td>
<td>1.01</td>
</tr>
</tbody>
</table>

Furthermore, the results present that the total amounts (in WWTPs) vary depending on the house connection rate. House connection rates fluctuate in huge amplitudes, depending on rural areas or urban areas, large cities, smaller cities, or even on the area of the city, [POGADE, F. et al. (2008), 6-22]. This fact has also been estimated in the fourth scenario and it amounts to about 1.15 million Mg dry solid matter of sludge accumulated in WWTPs. In this case, the population distribution in Vietnam has been implicated as a fact. The other calculation scenarios (Appendix A) are referring to the septic tanks problems. The population contribution and the application
THEORETICAL BASIS FOR THE CONCEPT

of septic tanks (urban/rural) are included in the different calculations. In Vietnam, operation and maintenance of septic tank (desludging, etc.) is fundamentally different from the typical requirements. Assuming that the septic tanks will be emptied in frequencies of three, six or nine years; the total amount of septage in Vietnam could be calculated to show the variations.

In practice, a lot of septic tanks in Vietnam cannot be emptied because of prevailing constraints (manhole, design, infrastructure, etc.). The comparison in Table 3-7 significantly marks wide variations based on the number of people which use a septic tank and on desludging frequencies.

Table 3-7: Septic tank amount in Vietnam [Appendix A]

<table>
<thead>
<tr>
<th>Desludging frequencies</th>
<th>4-people used septic tank [million m³ per year]</th>
<th>8-people used septic tank [million m³ per year]</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-Years</td>
<td>10.93</td>
<td>5.46</td>
</tr>
<tr>
<td>6-Years</td>
<td>5.46</td>
<td>2.72</td>
</tr>
<tr>
<td>9-Years</td>
<td>3.64</td>
<td>1.82</td>
</tr>
</tbody>
</table>

Information, literature and knowledge related to decentralized treatment systems, the number of facilities and scientific data related to sludge production are low developed and rarely published, [POGADE, F. (2011), p. 4]. The amount of produced sludge could not be estimated. The total dry mass of sludge produced during decentralized approaches can be assumed as a small quantity. With respect to the guideline (ATV-A 123), small treatment plants produce 0.3-2 (m³ /cap•a), [ATV (1986), p. 3]. However, the number of DWWTPs and the solid content (~2%) of decentralized systems is low but the volume can be estimated as large as the volume of septic tanks, [ATV (1986), p. 3]. In future, the number of DWWTPs will continue to grow.

3.1.4 Sludge composition

It is commonly known that sewage sludge from different sources can demonstrate large diversities in its physical, chemical and biological characteristics. Usually, sludge characteristics in their speciality vary depending on the country, part of the city and even time of the year. [HALL, J. E. et al. (1992), p. 3-17] In order to treat and dispose of the sewage sludge which is produced in WWTPs, the facility designer requires information about certain properties of the sludge, [L'HERMITE, P. (1991), p. 15]. As mentioned in the book, “(...) Physical parameters give general information on sludge processability and handlability. Chemical parameters are relevant to the presence of
nutrients and toxics/dangerous compounds, so they become necessary in the case of utilization in agriculture. Biological parameters give information on microbial activity and organic matter/pathogen presence, thus allowing the safety of use to be evaluated.” [TYAGI, R. D. (2009), p. 6-7] At present, there is an increasing objection against the reusing of sludge in agriculture, due to the high concentration of heavy metals and organic substances which pose risk for contamination, [L'HERMITE, P. (1991), p. 34-35]. Therefore, characterisation tests are crucial and the availability of laboratory or analytic equipment to analyse them is equally important, [L'HERMITE, P. (1991), p. 14-44]. In terms of re-use or disposal of sewage sludge, the composition plays a significant role. As to that, sludge status, hygienic aspects, water content, ratio between organic and inorganic matters, putrescibility, dewaterability, and the content of nutrients and pollutants have to mentioned particularly [KÜHN, V. (2008), p. 14]

3.1.4.1 Physical characteristics

3.1.4.1.1 Water content

The water content (WC) or moisture content of sewage sludge is the quantity of water contained in the material. In addition, the water content has an effect on volume and consistence of the sludge. [THOMÉ-KOZMIENSKY (1998), p. 116] According to the German standard (DIN 38414-2 (S 2) 1985-11), the water content can be expressed through the equation:

\[ WC = \frac{M_s - M_{TS}}{M_s} \times 100\% = \frac{M_W}{M_s} \times 100\% \quad [\%] \]

\( M_s \) Mass of sludge

\( M_{TS} \) Mass of dry solids

\( M_W \) Mass of water


The proportion of water in the sludge depends on the composition as well as on the size of the solid particles. Moreover, the WC enlarges with smaller sized solid particles and a higher content of organic dry substances. [THOMÉ-KOZMIENSKY (1998), p. 116] Depending on water content the consistence of sewage sludge changes as depicted in Table 3-8. In summary, Table 3-9 indicates typical European water content values for different sludge types.
3.1.4.1.2 **Dry residue**

The determination of dry residue (DR) is also guided by the German standard DIN 38414-2 (S 2) 1985-11 under equal conditions and it can be calculated with the equations given below:

\[ DR = \frac{M_d - M_w}{M_d} \times 100\% = \frac{M_{TS}}{M_2} \times 100\% \quad [\%] \]


3.1.4.1.3 **Total solid content / Dry solids**

Dry solids (TS) are \( M_{TS} \) in kilogram and defined by DIN 38414-2 (S 2) 1985-11. Therefore, 100 ml of the composite sample have to be scaled in a ceramic bowl. Thereafter, the sample has to be dried in an oven at a constant temperature of 105°C. The resulting dry solids in ratio to the initial weight produce the value of dry residues in mass-\%. [TENNhardt, L. (2004), p. 58]

3.1.4.1.4 **Dry substance**

In practice, the dry substance (DS) describes the dry solid concentration in contrary to the dry solids (TS). For this reason, it is denoted in g per litre. [THOMÉ-KOZMIESKY (1998), p. 117]
3.1.4.1.5  **Loss of ignition (volatile solids) / Ash content**

*Loss of ignition (DIN-EN 12879:2000)* is used as a general term for the content of organic substances in sewage sludge and it rather refers to the dry substance, [THOMÉ-KOZMIENSKY (1998), p. 117]. For determining the total dry substance of sludge, water has to be evaporated. After the drying process and the determination of the dry residue, the sample has to be annealed for two hours in the oven at a temperature of at 550°C. The ratio between annealed mass and total solid content can be calculated as a number of percentages of the total solids. [TENNHARDT, L. (2004), p. 58]

The mineral solid content (inorganic matter) can be weighted as the annealing residue of the dry substance according to DIN-EN 12879:2000. This is defined as *ash content*. [THOMÉ-KOZMIENSKY (1998), p. 117]

The measured parameter (*loss of ignition*) can be used for the determination of the load of the digester and the biogas yield. Below, Table 3-9 illustrates values for the loss of ignition and ash content referring to typical sludge types in Europe. The relation between loss of ignition, ash content and total solid content is expressed in the following equation:

\[
\text{loss of ignition} = \text{organic dry substance} = \text{total solid content} - \text{mineral solid content}
\]

[THOMÉ-KOZMIENSKY (1998), p. 117]

3.1.4.1.6  **Heating value**

The heating value is the total amount of usable heating energy produced by a complete combustion of one kilogram of fuel. Moreover, the heating value of sewage sludge depends on organic matter of dry substances inside the dry solids because only this organic fraction is accessible to the combustion process. Using the equation according to BATEN, the heating value \( H_u \) can be determined approximately. [THOMÉ-KOZMIENSKY (1998), p. 117-119]

\[
\Delta H_u = 20.9 \cdot \frac{MJ}{kg\ DS} \cdot C_{LT}
\]

\( \Delta H_u \)  Heating value (net caloric fraction)
\( C_{LT} \)  Concentration related to loss of ignition
Table 3-9: Comparison of specifications of raw sludge, waste activated sludge and different anaerobically digested sludge types in Europe [DICHTL, N. (2011), p. 5]

<table>
<thead>
<tr>
<th>Sludge characteristics</th>
<th>Raw sludge</th>
<th>Waste activated sludge</th>
<th>Digested sludge</th>
<th>Digested sludge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Badly digested</td>
<td>Well digested</td>
</tr>
<tr>
<td>pH-Value [-]</td>
<td>5.5 – 6.5</td>
<td>6.5 – 7.5</td>
<td>6.5 – 7.0</td>
<td>7.2 – 7.5</td>
</tr>
<tr>
<td>Total solids [%]</td>
<td>3 – 5</td>
<td>0.5 – 1.0</td>
<td>2.5 – 4.0</td>
<td>2.0 – 3.5</td>
</tr>
<tr>
<td>Loss of ignition [%]</td>
<td>60 – 75</td>
<td>55 - 80</td>
<td>&gt; 55</td>
<td>45 – 55</td>
</tr>
<tr>
<td>Acid consumption [mg CaCO₃/L]</td>
<td>500 - 1000</td>
<td>1000 – 2500</td>
<td>3000 - 4500</td>
<td></td>
</tr>
<tr>
<td>Org. acids [mg acetic acid/L]</td>
<td>1800 - 3600</td>
<td>2500 - 4000</td>
<td>100 - 1000</td>
<td></td>
</tr>
<tr>
<td>Spec. filter resistance [m/kg]</td>
<td>10¹³ - 10¹⁵</td>
<td>10¹³.⁵ - 10¹⁴.⁵</td>
<td>10¹³.⁵ - 10¹⁵</td>
<td>10¹²₅.⁵ - 10¹⁴</td>
</tr>
<tr>
<td>Heating value [MJ/kg TS]</td>
<td>14.8 – 18.7</td>
<td>14.8 – 20.9</td>
<td>&gt; 14.8</td>
<td>10.4 – 14.8</td>
</tr>
</tbody>
</table>

As per particular given in Table 3-9, raw sludge, waste activated sludge and anaerobically digested sludge are compared in its major sludge specifications. Sewage sludge treatments such as digestion, stabilisation and wet oxidation or other biodegradable processes, significantly converts organic matters such as its C- and H-content “(...) into a mixture of methane, the major component of natural gas, and carbon dioxide”. [ONYECHE, T. I. (1999), p. 38-39] As a general result of the microbiological processes, the organic matter is reduced, which also decreases the heating value (Table 3-9).

3.1.4.1.7 **Settleability**

The settling properties are characterised by measurements of the SVI. The Sludge Volume Index (SVI) describes a property that indicates the volume settling in a suspension after 30 minutes. Typically, SVI is used to depict settling characteristics and settling behaviours of particles in suspensions. [TYAGI, R. D. (2009), p. 1-36]
3.1.4.1.8 **Dewaterability**

The dewaterability is a technical graduator which estimates the dewatering behaviours of a suspension. For the moment, exact definitions could not be found\(^{11}\), [KOPP, J. (2009), p. 4]. Moreover, the organic matters of dry substances have a substantial influence on dewatering behaviour. In the second step of WWT, colloids are produced. These microorganism cells enclose water molecules and cause a limitation of the technical dewatering processes. [THOMÉ-KOZMIENSKY (1998), p. 117-119] Therefore, anaerobic digestion (stabilization) of raw sludge changes the particle size distribution which can affect the dewatering process. The interaction between digestion and the physical characteristics of the sludge leads to a reduction of the floc size in anaerobically digested sludge. [TYAGI, R. D. (2009), p. 1-36]

3.1.4.1.9 **Particle size distribution**

This parameter plays a major role in the choosing of aggregates to dewater sludge. Generally, raw sludge contains of large amounts of huge and small particles. In contrast, the particle size distribution of well anaerobically digested sludge is more homogeneous. [THOMÉ-KOZMIENSKY (1998), p. 117-119] The particle size can be changed by stabilization processes as explained in 5.2.3.

3.1.4.1.10 **Density**

The density of sludge can be assumed to be approximately 1 kg/m\(^3\) because of the high water content. For exact determinations of the specific sludge the equation below can help to calculate its correct density.

\[
\rho_s = \frac{\rho_w \cdot \rho_{DS}}{c_w \cdot \rho_{DS} + (1-c_w) \cdot \rho_w} \quad [kg/m^3]
\]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\rho_s)</td>
<td>sludge density</td>
</tr>
<tr>
<td>(c_w)</td>
<td>water content</td>
</tr>
<tr>
<td>(\rho_w)</td>
<td>water density</td>
</tr>
<tr>
<td>(\rho_{DS})</td>
<td>dry solid density ((\sim 2 - 2.5 \text{ kg/m}^3))</td>
</tr>
</tbody>
</table>

[THOMÉ-KOZMIENSKY (1998), p. 120]

\(^{11}\) „Begriffe wie Entwässerungsverhalten, Entwässerungseigenschaft und Entwässerbarkeit haben in der Sprache der Abwassertechnik einen festen Platz, eine scharfe Begriffsdefinition liegt jedoch nicht vor“, [KOPP, J. (2009), p. 4].
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In the following, the density for dried sludge are outlined:

- Bulk density (DIN EN 1236:1995): 0.37 – 0.86 Mg/m³
- Bulk density (tapped) (DIN EN 1237:1995): 0.45 – 0.99 Mg/m³

[KÜHN, V. (2008), p. 17]

In the following, other parameters are listed - filter velocity, specific filter resistance, compressibility, centrifugal behavior, sludge viscosity, rheology and strength. In the present paper, they cannot be elaborated in detail, but show the complexity of the physical properties of sludge. [THOMÉ-KOZMIENSKY (1998), p. 120-122]

3.1.4.2 Chemical characteristics

3.1.4.2.1 pH value

Normally, sewage sludge is arranged around the neutral pH value area, [THOMÉ-KOZMIENSKY (1998), p. 123]. For municipal sewage sludge, the pH value indicates its state of digestion and is an important indicator for the operation safety in anaerobic biological treatment plants, [KÜHN V. (2008), p. 20]. According to DIN 38 404-5 (1984), the pH value can be determined, [TENNHARDT, L. (2004), p. 57].

3.1.4.2.2 Nutrients

Sewage sludge has good prerequisites to be re-used in agriculture. Stabilised and hygienically harmless sludge can be characterised as a soil conditioner due to its humus content. However, sewage sludge should not be utilized in an unlimited and unregulated way in agriculture. The German ordinance of waste sludge (AbfKlärV) regulates the utilization of sewage sludge on agricultural and horticultural used soils. [THOMÉ-KOZMIENSKY (1998), p. 123] Outstanding nutrients in sewage sludge are nitrogen, phosphorous, potassium, magnesium and calcium, [KÜHN, V. (2008), p. 21]. Table 3-10 lists a number of regular nutrient values for more than 6000 sludge samples in Germany.
Sewage sludge exhibits a quantitative meaningful content of nitrogen and phosphorous (Table 3-10). In contrast, the potassium concentration in form of K₂O is low. Therefore, sewage sludge cannot be used by itself or without mineral addition of other fertilizers. [THOMÉ-KOZMIENSKY (1998), p. 123] Sewage sludge is categorized as a good phosphorous conditioner. Phosphorous is known as a very restricted natural nutrient resource worldwide. [ATV (1996b), p. 11] Taking into consideration the nutrients resource, sewage sludge becomes more and more attractive for agricultural use and as a biosolid, [EPSTEIN, E. (2002), p. 23-24].

3.1.4.2.3 Pollutants

Pollutants are created in natural way (natural pollutants) or they occur due to the human production influence (synthetic pollutants). All of them can already pose a risk in a very low concentration. During the contact, intake or input into the media, they can damage organism or the environment. [THOMÉ-KOZMIENSKY (1998), p. 124] In sewage sludge all kinds of pollutants can be found. They can be divided into the groups of organic and inorganic pollutants, [MfUN NRW (2004), p. 138-141]. In the last years, pollutants in sewage sludge have been discussed detailed. Examples for pollutant groups are: heavy metals, adsorbable organic halogen compounds (AOX), aromatic hydrocarbons, chlorobenzene, chlorinated hydrocarbons, chlorinated pesticides, chlorinated phenols, extractable organic halogens (EOX), hydrocarbons, musk compounds, polychlorinated dibenzo-p-dioxins, polychlorinated dibenzo-furan, polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), polychlorinated dibenzodioxin and –furan (PCDD/F), phthalates, tensides and linear alkylbenzene sulphonates. [MfUN NRW (2004), p. 4-5]

This present paper can only focus on a few of the pollutants in the sewage sludge and gives advice about dangers, the source pollutants and preventive measures related to the agricultural application of sewage sludge.
3.1.4.2.3.1 Heavy metals

Heavy metals are registered as metals with a density range from 3.5 to 5 g/cm³. Sewage sludge contains trace organics (micro-pollutants) like iron, nickel, molybdenum, selenium and wolfram which can be essential for micro-bacterial processes in low dose rates. [THOMÉ-KOZMIENSKY (1998), p. 124] The trace organics have to be dissolved and have to be biologically available, [KÜHN, V. (2008), p. 21].

Some of the compounds are resistant in nature. In the food chain, they appear to be a potential environmental risk and decrease food quality as well. In order to prevent health risks, standards should regulate the handling in sludge treatment, re-use and disposal (e.g. composting, digestion, waste incineration, agricultural application and landfill). [THOMÉ-KOZMIENSKY (1998), p. 124-125]

The intensity of toxicity varies depending on the concentration, the elements and the acceptors. During agricultural re-use and disposal, sewage sludge contacts the soil. A transfer from one medium to the other cannot be eliminated. As a consequence, heavy metal concentration accumulates in the food chain and eventually also in the human body. [THOMÉ-KOZMIENSKY (1998), p. 124-125] In Vietnam, standards (limits of heavy metals) for the utilization of sludge in agriculture should be obligatory to prevent toxic reactions and health damages.

Path I – landscape measures or agricultural use: Heavy metal → sewage sludge → soil/ground water → plant → animal → human.


Heavy metals which have been transferred from soil to plants can result in a loss of growth, decrease of harvest or quality defects. [KÜHN, V. (2008), p. 22] Minimal concentration of mercury, cadmium and lead in human or animal bodies induce health damages. Heavy metals have their main source in commercial and industrial activities, for instance in leather, pickling, textile, galvanic, pigment, battery, accumulator, print, ceramic, chemical and pharmaceutical industries. But also smaller sources can cause an immense heavy metal input. [THOMÉ-KOZMIENSKY (1998), p. 125] In Germany, the indirect dischargers have to exceed effluent standards of ATV-A 115. Due to the implementation, the heavy metal concentration has been reduced in the last years. [KÜHN, V. (2008), p. 22]

The Vietnamese equivalent is the “Technical Standard (TCVN)” or “National Technical Regulation (QCVN)” which has registered the allowable concentrations of
pollutants in the tables of **TCVN 5942, 1995** (chapter 2.4.1) and **QCVN 08: 2008/BTNMT** (chapter 2.4.2). [KLINGEL (2001), p. 4-10]

Before sewage sludge can be utilized as fertilizer, soil conditioner or for landscape measures in Germany, it has to be controlled according to the German ordinance of waste sludge (AbfKlärV). Thereby, allowable heavy metal concentration has to fall below in all parameters (Table 3-11). With stronger environmental efforts, the ordinance will become stricter in the future. [THOMÉ-KOZMIENSKY (1998), p. 125]

**Table 3-11: Allowable heavy metal concentration limits for agricultural re-use in Germany/ Europe** [THOMÉ-KOZMIENSKY (1998), p. 126]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average sludge concentration [mg/kg TS]</th>
<th>Germany</th>
<th>EG guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1982</td>
<td>1992</td>
</tr>
<tr>
<td>Cd</td>
<td></td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Hg</td>
<td></td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td>Cu</td>
<td></td>
<td>1200</td>
<td>800</td>
</tr>
<tr>
<td>Zn</td>
<td></td>
<td>3000</td>
<td>2500</td>
</tr>
<tr>
<td>Pb</td>
<td></td>
<td>1200</td>
<td>900</td>
</tr>
<tr>
<td>Ni</td>
<td></td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Cr</td>
<td></td>
<td>1200</td>
<td>900</td>
</tr>
</tbody>
</table>

3.1.4.2.3.2 *Organic pollutants*

Determination and allowable concentration of organic pollutants have been regulated by the German ordinance of waste sludge (AbfKlärV). Sewage sludge that should be used in agriculture has to meet the limits of its standards of the ordinance. In Table 3-12, the allowable organic pollutant concentrations have been summarized. [THOMÉ-KOZMIENSKY (1998), p. 128]

*Polychlorinated dibenzodioxin and dibenzofuran (PCDD/PCDF)* are used as collective name for a pollutant group which consists of 210 different chemical compounds altogether. The properties of the several chemical compounds vary in their environmental interactions. Seven chemical compounds of PCDD and ten of PCDF are immensely toxic. Their matters are expressed in one term – toxic equivalents (TE). The calculation of TE requires the determination of each chemical compound of these 17

² Planned.
THEORETICAL BASIS FOR THE CONCEPT

toxic PCDD/F in ng/kg M\textsubscript{TS}. Subsequently, they have to be multiplied with their individual “SEVESO”-poison factor. The result of this calculation presents the total toxicity equivalent for the 17 toxic PCDD/Fs. In the 1980s, the dioxin concentrations of wastewater and waste sludge have fractionally reached high values in different German counties. On average, the concentration amounted up to 220 ng TE/kg M\textsubscript{TS} (Table 3-12). Afterwards, several researches on PCDD/F concentration (e.g. by ATV and BMU) were conducted and delivered results showing lower concentration rates. Following this, the allowable limit was fixed to 100 ng TE/kg M\textsubscript{TS} (Table 3-12). [THOMÉ-KOZMIENSKY (1998), p. 128]

**Polychlorinated biphenyls (PCB)** are chlorinated hydrocarbons which are produced during the chlorination of biphenyl in presence of an ironchlorid-catalyzer. Due to their high electrical resistance, they can be applied in isolation, hydraulic and cooling fluids. PCBs are listed as biologically resistant substances. Six of 209 PCB compounds – PCB 28, 52, 101, 138, 153 and 180 – are consulted for analysing the PCB contamination. Former sewage sludge analysis showed high PCB contamination in sewage sludge and soil. On multiple sludge fertilized agricultural lands, higher and extreme values were analysed. Worldwide, the production and application of PCB has been limited or forbidden. Affected by this, the concentration was significantly reduced. Table 3-12 below demonstrates PCB values and the established allowable limits. [THOMÉ-KOZMIENSKY (1998), p. 128-129]

**Adsorbable organic halogen compounds**, the abbreviation AOX stands for adsorbable organic halogens. “X” is the variable that can be transformed with elements of the seventh main group of the periodic table – fluorine, chlorine, bromine, iodine and astatine. The legislative body classified AOXs as hazardous substances because of their tough biodegradability, biological resistance, ecotoxicological character, toxic effect, bioaccumulation and their nearly exclusive anthropogenic source. AOXs are regulated by the German ordinance of waste sludge (AbfKlärV) as summation parameters, the allowable concentration is located at 500 mg AOX/kg TS (Table 3-12). AOXs derive from industrial and commercial waste water, municipal or domestic waste water, precipitation as well as run off. To prevent wastewater and waste in their quality and quantity, all endeavors have to be made at the sources (indirect dischargers). In general, the AOX concentration in sewage sludge tends to decrease in Germany. [THOMÉ-KOZMIENSKY (1998), p. 129]
Polycyclic aromatic hydrocarbons (PAH) indicate the chemical range which consists of minimal two condensed benzene rings, including only C and H atoms in its molecule. Furthermore, PAH are categorized as hazardous substances based on their tough biological degradability and resistance. PAH are taken up by plants in different ways. In consideration of PAH soil accumulation, a certain risk for human health cannot be eliminated. [THOMÉ-KOZMIENSKY (1998), p. 130]

Detailed information about endocrine disruptors can be found in research reports published by the University of Technology Dresden. A low-rate exposure to endocrine disrupting substances can effect a hormonal change in organisms. [TENNHARDT, L. (2004), p. 5-7] Another suggestion for further literatures is [Drescher-Kaden, U. (1995)] and [MfUN NRW (2004), Part D or E]

Table 3-12: Average organic pollutants concentration, standards in Germany (AbfKlärV) [THOMÉ-KOZMIENSKY (1998), p. 128]

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AOX</td>
<td>mg/kg TS</td>
<td>500</td>
<td>177</td>
<td>202.5</td>
<td>148.14</td>
<td>193.19</td>
</tr>
<tr>
<td>PCB 28</td>
<td>mg/kg TS</td>
<td>0.2</td>
<td>0.1</td>
<td>0.039</td>
<td>0.010</td>
<td>0.003</td>
</tr>
<tr>
<td>PCB 51</td>
<td>mg/kg TS</td>
<td>0.2</td>
<td>&lt; 0.01</td>
<td>0.039</td>
<td>0.007</td>
<td>0.003</td>
</tr>
<tr>
<td>PCB 101</td>
<td>mg/kg TS</td>
<td>0.2</td>
<td>0.01</td>
<td>0.039</td>
<td>0.009</td>
<td>0.011</td>
</tr>
<tr>
<td>PCB 138</td>
<td>mg/kg TS</td>
<td>0.2</td>
<td>0.02</td>
<td>0.041</td>
<td>0.017</td>
<td>0.023</td>
</tr>
<tr>
<td>PCB 153</td>
<td>mg/kg TS</td>
<td>0.2</td>
<td>0.02</td>
<td>0.042</td>
<td>0.017</td>
<td>0.023</td>
</tr>
<tr>
<td>PCB 180</td>
<td>mg/kg TS</td>
<td>0.2</td>
<td>0.02</td>
<td>0.041</td>
<td>0.011</td>
<td>0.011</td>
</tr>
<tr>
<td>PCDD/F</td>
<td>ng TE/kg TS</td>
<td>100</td>
<td>15.8</td>
<td>23.88</td>
<td>9.33</td>
<td>11.99</td>
</tr>
</tbody>
</table>

Municipal wastewater treatment and agricultural re-use of sludge contribute considerably to the contamination of water and soil. Sustainable sludge management should aim at a reduction of the emission of pollutants to a minimum.

3.1.4.3 Biological characteristics

Wastewater treatment uses several bacterial colonies and fungi for water cleaning processes. In sewage sludge, hundreds of organism species are concentrated. [THOMÉ-KOZMIENSKY (1998), p. 130-131]

3.1.4.3.1 Pathogens

Primary sludge or raw sludge can contain pathogenic organisms, eggs of parasites and viruses etc. that originate from animal and human excreta. Therefore, the handling of sludge has to be classified critical due to its epidemic properties. [KÜHN, V. (2008), p. 26] Additionally, much attention should be focused on the transmission of animal diseases through sewage sludge re-use, with a view to epidemics like BSE, foot and mouth disease and bird flu. Experts attach little value to the risk that prions (proteinaceous infectious particles) in "(...) sewage sludge can attain due to the soil path into plants or water." [FRICKE, K. et al. (2001), p. 55]

Biological mechanic treatment should be applied to eliminate pathogenic organisms. A hygienic treatment is necessary due to fact that exposures towards humans and animals are possible. Evidently, it is quite save that a reduction of pathogens can be guaranteed through mesophilic or thermophilic digestion or well-operated composting. Otherwise, an extra disinfection step is required. [THOMÉ-KOZMIENSKY (1998), p. 131]
4 MUNICIPAL WASTEWATER TREATMENT PLANTS

4.1 DEWATS

DEWATS – Decentralized wastewater treatment systems were developed by a network of organisations and experts, whereby several different options of comprehensive wastewater management, improved sanitation strategies and socio-economic aspects were taken into consideration. [ULRICH, A. et al. (2009), p. 13-34] Decentralized wastewater treatment is defined by [POGADE, F. (2010), p. 2] as “a concept to provide sanitation solutions in areas not yet connected to centralized waste water treatment plants, or areas that do not allow a connection to centralized treatment plants, (...) this is the crucial point - where waste water is treated at or near the point of generation.”

Figure 4-1: DEWATS concept [HAUCKE, J. (2010), p. 11]

In many cases, decentralized facilities are “No-sewer-treatment plants” due to the fact that a decentralized system does not need a conventional sewer system, but it requires feeding pipes (Figure 4-1). The systems can be allied for different areas, ranging from rural and from peri-urban to urban areas. [GTZ (2010), p. 9] In Figure 4-1, the typical application of decentralized systems in practice on a communal or provincial level is shown. The rather negative evaluation to follow is mentioned in the report of [POGADE, F. (2011), p. 4] “Probably hundreds of DWWT plants have been constructed all over Vietnam so far. However, information and experiences have rarely been pub-
lished, the potential of learning from these lessons has rarely been tapped. Many experts believe that the vast majority of the plants is not operational any more, or has never been.” The scheme in Figure 4-2 demonstrates an alternative which could be an appropriate solution for Vietnam. The idea behind the structured arrangement is to combine centralized and decentralized approach. This solution, as simplified in Figure 4-2, provides safe wastewater management in all areas (center, suburbs and outskirts). [POGADE, F. (2010), s. 19-25]

Figure 4-2: Combined system – example Vietnam [POGADE, F. (2010), s. 19-25]

“The Wastewater and Solid Waste Management Project“, in cooperation with the MoC is currently preparing a joint approach to develop decentralized wastewater treatment in Vietnam’s urban areas. This decentralized approach will be a supplementation to centralized treatment activities. Centralized solutions are of the highest importance and relevance to the cities in Vietnam, but also decentralized solutions are featuring specific advantages. [POGADE, F. (2010), p. 2]

4.2 WASTE WATER MANAGEMENT PROGRAM

“Wastewater and Solid Waste Management in Provincial Centers” is a program sponsored by the German Government. The main purpose of WMP is to develop enhanced wastewater management. The service is provided in six provincial urban cities in Vietnam (Figure 4-3). The environmental conditions, namely water quality including drainage, channels and rivers should be enhanced and seasonal inundations should be reduced. [GTZ (2010), p. 1] The project encloses two main modules:

- “Financial Cooperation (FC), jointly financed by the German Development Bank (KfW) and the Government of Vietnam (GoV), and
• Technical Cooperation (TC), implemented by the German Technical Cooperation Agency (GTZ) and the German Development Service (DED), in close cooperation with the Ministry of Construction (MoC).” [GTZ (2010), p. 1]

The first module (FC) concentrates on better conditions like new infrastructure for treatment of wastewater and solid waste. The other module (TC) currently zooms into the two outlined fields:

• “TC Component 1: Capacity Development for the MOC, and
• TC Component 2: Capacity Development for Wastewater Management, also referred to as the WWM project” [GTZ (2010), p. 1]

Today, TC Component 2 (WWM), concentrates on operating capacity building services at local governments and public wastewater companies in six provincial urban centers in Vietnam, including the cities of Bac Ninh, Hai Duong, Vinh, Can Tho, Soc Trang and Tra Vinh. (Figure 4-3)

Furthermore, the design of pilot plants and “(...) raising of awareness among decision makers on decentralized wastewater treatment (DWWT) approaches for urban or semi-urban areas in the outskirts of cities that are not served by centralized wastewater collection and treatment systems is a major focus of the component.” [GTZ (2010), p. 1]

Figure 4-3: Project facilities in Vietnam [INWENT (2010), p. 118]

Additionally, a few new provincial cities (Hoa Binh, Son La, Lang Son) have accepted to be supported for the WWP. [GIZ (2010), p. 1]
4.2.1 Results of sludge analysis

During the production phase of this paper, different analysis have been carried out: centralized systems, decentralized systems, sewer systems and septic tanks, to present a general survey of sludge types in Vietnam. Moreover, other projects or programs could provide sludge samples of surface water sludge (Lake Hoan Kiem) and industrial sludge (Can Tho). The purpose of the sampling and analysis is to elaborate the composition of several delivered raw matters in the sludge treatment facility. Therefore, Table 4-1 outlines a wide range of sludge from centralized systems, decentralized systems, sewer systems, septic tanks, lake and industrial sludge. The centralized sludge (Table 4-1) was sampled in a three-years processing anaerobic wastewater treatment plant in Da Nang City. The treatment capacity of this plant is 40,000 m³ per day (anaerobic ponds) and it is located in a suburban area. The DEWATS in the commune Kieu Ky, Gia Lam district, was the major research area for this analysis. The Gia Lam district is an urban area which belongs to Hanoi City and has around 230,000 inhabitants. The decentralized wastewater treatment plant was reviewed many times in different seasons. Parallel to the sludge sampling, water quality samples have been elaborated. The DWWTP is designed to process 40 m³ per day. In the catchment area of this facility, the other sludge was sampled from the sewer system and the septic tank. In Vietnam, it is very difficult to find a septic tank with a manhole. As a general rule, the tanks are positioned under the basement of the building, in the kitchen or in the courtyard. In order to get samples, the concrete has to be broken open to get access to the system. All sludge samples have been assayed by using a sludge pipe. To guarantee the homogeneity of the sample, the pipe volume was stored in a bucket and mixed with blunger. Composite sample have been taken while the mixtures were reaching the homogeneity status. The samples were analyzed by different laboratories, in Hanoi and in Dresden (Figure 4-4). The chart below compares the TS of the same samples. The only reason for such a high fluctuating TS is an insufficient mixture or the use of “different” analysis methods to determine the total solid content at the laboratory in Hanoi.

![Figure 4-4: Comparison of the analysis results (TS)](image-url)
### Table 4-1: Overview of sludge types in Vietnam

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
<th>Centralized system (anaerobic ponds in Da Nang)</th>
<th>Decentralized system (anaerobic baffled reactor in Kieu Ky)</th>
<th>Septic Tank (Kieu Ky)</th>
<th>Sewer (Sewer system Kieu Ky)</th>
<th>Surface Water (Lake Hoan Kiem)</th>
<th>Industrial area (industrial area, Can Tho, Export companies for food and drinks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH-Value</td>
<td>[-]</td>
<td>7.76</td>
<td>7.51</td>
<td>7.21</td>
<td>6.64</td>
<td>7.5</td>
<td>7.4</td>
</tr>
<tr>
<td>Water Content</td>
<td>[%]</td>
<td>97.66</td>
<td>97.82</td>
<td>99.29</td>
<td>96.12</td>
<td>95</td>
<td>99.55</td>
</tr>
<tr>
<td>Total Solid Content (TS)</td>
<td>[%]</td>
<td>2.34</td>
<td>2.18</td>
<td>0.71</td>
<td>13.88</td>
<td>5</td>
<td>0.45</td>
</tr>
<tr>
<td>Loss of ignition</td>
<td>[%]TS</td>
<td>28.19</td>
<td>13.47</td>
<td>67.63</td>
<td>21.69</td>
<td>13.5</td>
<td>-</td>
</tr>
<tr>
<td>Ash content</td>
<td>[%]TS</td>
<td>71.81</td>
<td>86.53</td>
<td>32.37</td>
<td>78.31</td>
<td>86.5</td>
<td>-</td>
</tr>
<tr>
<td>Heating Value</td>
<td>[KJ/kgTS]</td>
<td>5'574</td>
<td>5'028</td>
<td>22'274</td>
<td>4'801</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### Nutrients

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
<th>Centralized system (anaerobic ponds in Da Nang)</th>
<th>Decentralized system (anaerobic baffled reactor in Kieu Ky)</th>
<th>Septic Tank (Kieu Ky)</th>
<th>Sewer (Sewer system Kieu Ky)</th>
<th>Surface Water (Lake Hoan Kiem)</th>
<th>Industrial area (industrial area, Can Tho, Export companies for food and drinks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Nitrogen</td>
<td>[%]TS</td>
<td>1.51</td>
<td>1.04</td>
<td>5.48</td>
<td>0.71</td>
<td>0.7</td>
<td>7.59</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>[%]TS</td>
<td>0.57</td>
<td>0.61</td>
<td>0.88</td>
<td>0.5</td>
<td>1.5</td>
<td>1.89</td>
</tr>
<tr>
<td>Total org. Carbon (TOC)</td>
<td>[%]TS</td>
<td>8.14</td>
<td>0.059</td>
<td>19.52</td>
<td>14.1</td>
<td>6.5</td>
<td>7.59</td>
</tr>
<tr>
<td>Total inorg. Carbon (TIC)</td>
<td>[%]TS</td>
<td>0.160</td>
<td>1.10</td>
<td>0.16</td>
<td>1.18</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ammonium (extracted through water)</td>
<td>[%]W</td>
<td>0.052</td>
<td>0.043</td>
<td>0.118</td>
<td>0.069</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nitrate (extracted through water)</td>
<td>[%]W</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>[mg/kg]</td>
<td>3076.92</td>
<td>2556.8</td>
<td>952.38</td>
<td>2128.44</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>[mg/kg]</td>
<td>1934.52</td>
<td>5239.2</td>
<td>2382.66</td>
<td>4759.33</td>
<td>6674</td>
<td>-</td>
</tr>
</tbody>
</table>

#### Heavy metals

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
<th>Centralized system (anaerobic ponds in Da Nang)</th>
<th>Decentralized system (anaerobic baffled reactor in Kieu Ky)</th>
<th>Septic Tank (Kieu Ky)</th>
<th>Sewer (Sewer system Kieu Ky)</th>
<th>Surface Water (Lake Hoan Kiem)</th>
<th>Industrial area (industrial area, Can Tho, Export companies for food and drinks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead (Pb)</td>
<td>[mg/kg]</td>
<td>114.84</td>
<td>101.78</td>
<td>20.15</td>
<td>71.12</td>
<td>182</td>
<td>-</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>[mg/kg]</td>
<td>3.87</td>
<td>1.75</td>
<td>5.51</td>
<td>1.51</td>
<td>b.d.l.</td>
<td>-</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>[mg/kg]</td>
<td>144.43</td>
<td>54.75</td>
<td>18.71</td>
<td>40.81</td>
<td>111</td>
<td>-</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>[mg/kg]</td>
<td>260.00</td>
<td>110.69</td>
<td>410.69</td>
<td>146.85</td>
<td>145</td>
<td>-</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>[mg/kg]</td>
<td>114.93</td>
<td>63.57</td>
<td>34.07</td>
<td>48.33</td>
<td>42</td>
<td>-</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>[mg/kg]</td>
<td>1.430</td>
<td>0.18</td>
<td>0.159</td>
<td>0.738</td>
<td>3.78</td>
<td>-</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>[mg/kg]</td>
<td>3289.47</td>
<td>792.85</td>
<td>2600.35</td>
<td>644.63</td>
<td>521</td>
<td>-</td>
</tr>
</tbody>
</table>

#### Organic pollutants

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
<th>Centralized system (anaerobic ponds in Da Nang)</th>
<th>Decentralized system (anaerobic baffled reactor in Kieu Ky)</th>
<th>Septic Tank (Kieu Ky)</th>
<th>Sewer (Sewer system Kieu Ky)</th>
<th>Surface Water (Lake Hoan Kiem)</th>
<th>Industrial area (industrial area, Can Tho, Export companies for food and drinks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOX</td>
<td>[mg/kg]</td>
<td>78.6</td>
<td>102.3</td>
<td>80.6</td>
<td>178.7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PCB</td>
<td>[mg/kg]</td>
<td>&lt; 0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PAH</td>
<td>[mg/kg]</td>
<td>&lt; 0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Sources: WC, TS ,Loi, AC, H2 - [TUD - IAA Pirna, Prof. Bilitewski]; pH, nutrients, heavy metals - [VAST- Department of Analytical Chemistry, Prof. Duc Loi]; organic pollutants - [VAST- Department of Environmental Toxic Analysis, Dr. Nguyen Quang Trung]; lake Hoan Kiem [LORBEER, H. et al (2009)]; industrial area - [FELDHAUS, H. (2011)]
Normally the **pH-value** of the samples varies between 7 and 8. Only the sludge from sewer systems undergoes 7. Due to the long retention time of sludge in natural slope designed sewers, biodegradation processes (hydrolysis) have been started and reduced the pH-value. The **water content** ranges from approximately 99.5 to 95 %. The sewer system presents a low water content (86.12%) because of sedimentation residues which have settled in the sewer. The **total solid content** is the equivalent value to the water content. The TS content varies from 0.5 to 5 % and is equal to European sludge values (Table 3-9). Returned sludge from the industrial companies is very low concentrated. The **loss of ignition** (volatile solids content) indicates the organic part of the solid content. Mostly unstabilized sewage sludge in Europe contains 60 to 75 % in the dry weight basis (Table 3-9). The results of VAST (Hanoi) and IAA (Dresden) are presented in the chart (Figure 4-5). Moreover, the diversity of the detected values is shown in Figure 4-4. High differences between the analytic results of the loss of ignition are found. The reason for this is that the laboratory “Hanoi” have been applied “other” (wrong) analytical methods. In general, the results show a low content of organic dry matter. On average 21.12 % volatile solids content for sewage sludge in Vietnam falls far below the European value (Table 3-9). Only the septage with 67.63 % volatile solids content corresponds with conventional values in Europe.

![Figure 4-5: Comparison of the analysis results (LoI)](image)

Reasons for the low dry organic content can be biodegradation due to other climatic conditions and long retention time of sludge or wastewater in the sewer systems. Furthermore, the different hygienic habits (usage of toilet tissue) and waste collection on the street plays an important role. A large amount of inorganic matter during street cleaning or lacking street cleaning can be washed into the sewers and this can cause a change of the ratio between organic and inorganic matter of the solid content.
The utilization of septic tanks reduces through its accumulation of solids the organic matter in sewer system.

The **ash content** is three-times higher than typical values of European countries (Table 3-9). This parameter is the inorganic matter of the total solid content and is the equivalent value to loss of ignition.

With about 5'000 kJ per kg\(_{TS}\) the **Heating value** is four times lower than the general values of raw sludge in Europe. Smaller values of loss of ignition are registered and lead to a lower energy content of Vietnam’s raw sludge. The septic tanks sludge has confirmed expected heating values (22'274 kJ per kg\(_{TS}\)). In this case, wastewater input is estimated to be composed of differently. It may be possible that food residues are discharged of in the septic tanks.

All sludge types have a high concentration of **nutrients**. The sludge shows valuable agronomic properties for **Nitrogen, Phosphorous, Potassium** and **Magnesium**. In particular, the food industry producers have a remarkable content of nutrients.

In all samples, **Heavy metals** could be observed and in two particular cases the specific metal limit according to the German ordinance of waste sludge is exceeded (Table 3-11). The centralized sludge and the septage exceed the allowable **Zinc** limit of 2500 mg/kg TS (German ordinance of waste sludge - AbfKlärV). An agricultural application therefore is forbidden in these cases. In particular, **Cadmium** is an important indicator and all concentration values do not exceed the German limits. The septic tanks value (normal household) demonstrates the highest concentration of Cd-value. The **Mercury** concentrations confirm the accumulation rule of metals from smaller up to large-scale approach. For all analyzed samples, **Chrome, Copper, Lead** and **Nickel** do not exceed the allowable limits of the German ordinance of waste sludge.

The analysis of **organic pollutants** was limited to the determination of the PCB, PAH and AOX. Other organics in the sludge could not be detected in Vietnam. The peak of the results with 178.7 mg AOX per kg TS was found in Kieu Ky’s sewer system and the centralized sludge presents the lowest result (78.6 mg AOX/kg TS). None of the values exceeded the limits of the German ordinance of waste sludge - 500 mg/kg AOX (AbfKlärV). **PCB’s and PAH’s** have been determined and for all sludge samples the concentration of 0.005 mg per kg TS is not exceeded.

All in all, the analysis involved a quantity of **8 wastewater samples** and **4 sludge samples**. The **total costs** for the entire analysis are **VND 32'000'000 (€ 1070)**, exempted analysis costs in Germany (Dresden University of Technology) and other additional costs.
4.3 LEARNED OUTCOMES

For wastewater treatment plants:
- Rising drinking water consumption / increase of wastewater production,
- Lack of wastewater sewerage and low house connection rate,
- Limitation of wastewater treatment facilities and capacity,
- Wastewater proceedings are very limited (less than 10%), untreated wastewaters are directly discharged (operation and maintenance problems (financial problem)),
- Environmental impacts and further problems (pollution, contamination, health risks),
- Construction of new wastewater facilities / low construction quality,

For the legal and institutional framework:
- Institutional problems (state-owned companies, annual and non-performance related budget, ineffective wastewater fees at public level),
- Problems of implementation processes at local and communal levels,
- Low environmental awareness and environmental law statute (small penalties / fines, low pressure by enforcing authorities) “polluter pays” principle needs to be enforced,
- Responsibilities are overburdened (quantity/quality of staff, low salary, low motivation),

For urban sludge management:
- Sludge amount increases / lack of sludge treatment plants (only 4% treated),
- Sludge is not considered in a adequate way in wastewater treatment processes,
- Capacity of sludge treatment and disposal are insufficiently developed,
- Legislations and decisions do not regulate the urban sludge management entirely
- Untreated sludge is dumped illegally (sea, river, lakes, fishponds, channel, landfills),
- Private septic tanks are not regularly constructed, operated and maintained,
- Septic tank constructions refuse the access, emptying as well as efficient operation,
- Septic tanks offer special on-site conditions (city infrastructure, manhole deficits),
- Missing researches and analysis of sludge at all levels,
- Lack of sludge statistics (place of generation, amount, composition, treatment),
- Public and political awareness is inadequate,
- Sludge composition is different compared to European sludge,
- Need of fertilizers (price increase, production deficit),
- Unprofitable composting site/ deficient of waste incineration plants/ boom of biogas,
- Landfill capacity and land resource is limited,
- Low financial budgets, but urban sludge management solutions are required.
5  SLUDGE TREATMENT AND DISPOSAL OPTIONS

5.1 GOALS OF SLUDGE TREATMENT

In the previous chapters (2 and 3), the legal situation in Vietnam and the sludge information background (types, total amount, volume, characteristics, etc.) are explained. Based on this information, an integrated sewage sludge treatment and disposal concepts will be designed and formulated.

The main long-term objective of sludge treatment and disposal is to handle the residues of the wastewater treatment without significant impact on the environment. Therefore, sludge can be stored temporarily, treated, processed and afterwards reused for landscape measures or in agriculture or at least disposed of without negative impacts on the environment (as shown in Figure 5-1). Dewatering / drying characteristics or processes have to be considered because of the prime importance to reduce the total volume. [KÜHN, V. (2008), p. 29-30]

Figure 5-1: Survey of processes of a complete sludge treatment [DICHTL, N. (2011), p. 7]

All in all, the following key points illustrate the importance of a proper sewage sludge treatment:
SLUDGE TREATMENT AND DISPOSAL OPTIONS

- Volume reduction via minimization of water and solid content - necessary for treatment, storage, transport, re-use and disposal;
- Organic matter reduction by aerobic or anaerobic stabilization - can economically minimize and prevent any odorous impact on the public (extra: improvement of dewaterability);
- Epidemiological pathogens have to be decreased to the least possible extent (sewage sludge can never be considered as sterile);
- Stabilized sludge, a humus- and nutrient-rich matter, can be utilized as biosolid in agriculture and for landscape measures;
- Prevention of emission greenhouse gases, usage of the produced biogas to recover energy for the process chain.


Sludge management has to take into account technical, logistical, economical, and environmental, but also legal, social and political aspects, as detailed shown in Figure 5-2, [THOMÉ-KOZMIENSKY (1998), p. 139].

![Figure 5-2: Framework for sludge management](image-url)


[THOMÉ-KOZMIENSKY (1998), p. 139]
5.2 PROCESSING ELEMENTS

It is not permitted to directly re-use or dispose of untreated sludge, such as raw sludge, because of its water content, epidemiological risk and smell. Therefore, sludge requires primary treatment. Below, the necessary and available processing elements are presented in brief. [THOMÉ-KOZMIENSKY (1998), p. 141-142]

- Pre-treatment elements (on-site)
- Transportation
- Stabilization
  - Disintegration (pre-treatment)
  - Aerobic stabilization- (wet-composting)
  - Anaerobic stabilization – digestion
  - Chemical thermal stabilization
  - Enhancement of stabilization
- Disinfection
- Removal of water
  - Thickening and stacking
  - Dewatering
    - Natural dewatering
    - Mechanical dewatering
  - Drying
    - Convection drying
    - Contact drying
  - Combined dewatering and drying
- Agricultural uses and landscape measures
- Biological re-uses
  - Composting with organic wastes
  - Fermentation with organic wastes
- Thermal disposal (energy recovery)
  - Degasification / Gasification
  - Mono-incineration
  - Melting
  - Combined processes
  - Co-incineration
  - Wet-oxidation
- Disposal on landfill sites
5.2.1 Pre-treatment

Primary treatment or more exactly pre-treatment of sludge is a necessary operation step when it comes to the decentralized approach. The main objective is to dewater and reduce the volume of the sludge and then transport it to further treatment. Decentralized wastewater treatment plants in most cases do not have any existing sludge treatment aggregates on-site. [ULRICH, A. et al. (2009), p. 306-335] Generally, DWWTPs gather the amount of sludge at the bottom of the treatment units. Sludge removal should be practiced by well-trained personnel. Particularly in anaerobic systems, methane, H₂S and other trace components are produced, creating a possible danger and risk of suffocation. The major purpose of desludging is to remove the older and already degraded sludge. Nevertheless, the active top layer sludge should remain in the system. The desludging process can be implemented through buckets, pumping, hydraulic pressure or by using vacuum tankers. [ULRICH, A. et al. (2009), p. 306-308]

- Bucket use is not necessarily recommended because this can pose health risks for workers and the above described operation needs cannot be complied,
- Pumping demands a good sludge pumping aggregate, which can be a free-flow rotary pump, to avoid clogging effects,
- Hydraulic desludging is running without energy demand but this hydraulic process has to be provided in the construction design. If this is possible on-site, it can be practiced with the aid of installed pipes at the bottom units (Ø 0.35-0.50m),
- Vacuum tankers and mobile tankers, can desludge the necessary units and transport the matter to the next sludge treatment plant. Expensive vacuum tanker models can dewater the sludge at the same time,
- Additionally, mobile dewatering methods should be considered to reduce the transport volume.

In all urban zones, generated sludge from decentralized units (including septage sludge from on-site septic tanks or pit latrines) has to be transported to the semi-central or central processing treatment plant, covering the centres, suburbs and outskirts of the city zone. Sustainable treatment and disposal options are elaborated more precisely in chapter 6.
5.2.2 Transportation

For the transportation of sludge individual vacuum tankers need to be provided (Figure 5-3). Therefore, the processes requires to be optimized, “The transportation of waste over long distances in small vehicles is uneconomical”, as reported in [INVENT (2009), p. 116]. Moreover, collection in accessible waste stations must be implemented. In general centralization of treatment has become a lot more economical for urban areas which generate huge waste quantities. [INVENT (2009), p. 116] Different kinds of transportation systems should be utilized, depending on special required on-site conditions (different dimensions, structural and technical equipments). These prevailing conditions should be taken into account when planning the transportation systems. [INVENT (2009), p. 116-124].

Figure 5-3: Vacuum tanker [AECOM (2008), p. 122]

5.2.3 Stabilization

The main objective of stabilization processes (Figure 5-1) is to reduce the organic matter, biological activity as well as the acrogenic ingredients. Secondary aims are the decreasing of pathogens and an increasing of dewatering behaviours. Up until the technical barrier of 55 to 60 % of the organic matter can be biodegraded. The total solid content can be minimized down to 35 %. [THOMÉ-KOZMIENSKY (1998), p. 142] Biological metabolism depends on temperature levels. Therefore, different process temperature can be applied and are subdivided in:

- Psychrophilic process 0 – 30 [°C]
- Mesophilic process 25 – 45 [°C]
- Thermophilic process 45 – 80 [°C]
Stabilization demands depend on the further disposal paths, as depicted in Table 5-1. Well pasteurized sludge can be obtained through utilization of mesophilic processes and thermophilic processes but it cannot be considered as sterile. The stabilization leads to a significant reduction of the heating value due to of biological degradation processes. [THOMÉ-KOZMIENSKY (1998), p. 142]

Table 5-1: Stabilization requirement [THOMÉ-KOZMIENSKY (1998), p. 142]

<table>
<thead>
<tr>
<th>Action destination</th>
<th>Demanded stabilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landscape measures, agriculture (liquid)</td>
<td>full-stabilized, relatively disinfected</td>
</tr>
<tr>
<td>Re-use for landscape measures, agriculture</td>
<td>partly stabilized or fully-stabilized</td>
</tr>
<tr>
<td>Material recycling e.g. construction material</td>
<td>non-stabilized to fully-stabilized</td>
</tr>
<tr>
<td>Sludge lagoons</td>
<td>fully-stabilized or relatively stabilized</td>
</tr>
<tr>
<td>Landfill (dewatered)</td>
<td>relatively stabilized to fully-stabilized</td>
</tr>
<tr>
<td>Landfill (dried)</td>
<td>relatively stabilized to fully-stabilized</td>
</tr>
<tr>
<td>Landfill (ash e.g. incineration)</td>
<td>non-stabilized combustion</td>
</tr>
</tbody>
</table>

5.2.3.1 Disintegration

In the fields of sludge treatment, disintegration means a mechanical process in which cell walls of biological organisms are broken down. The benefit of this application can be used to decrease the available biodegradable matter. Sludge can be stabilized more efficiently. The practical approach is researched and tested - by Prof. Dichtl and the results seem to be well-functioning. [THOMÉ-KOZMIENSKY (1998), p. 143]

5.2.3.2 Aerobic stabilization (wet-composting)

In the presence of oxygen, biological organisms can degrade the organic matter of sludge. The oxygen is dissolved in water and has to be supplied for these treatment methods. [THOMÉ-KOZMIENSKY (1998), p. 143] In aerobic systems, micro-organisms directly degrade organic matter into carbon dioxide, water and organic material with introduced energy (oxygen). [ONYECHE, T. I. (1999), p. 38-39], as simplified illustrated in Figure 5-4.
This treatment application finds the optima in small-scale facilities until 10’000 PE. The sludge load (TS) should not exceed the quantity of 0.05 kg BSB₅/Kg•d. The aeration can hardly be provided in large-scaled facilities. The aerobic stabilization is able to treat highly toxic sludge, e.g. industrial sludge. In comparison to the digestion process, the biodegradation rate of the organic matter is relatively low (30-40%). Due to the energy input, the operating cost is higher than that for anaerobic treatment methods. [THOMÉ-KOZMIENSKY (1998), p. 143]

5.2.3.3 Anaerobic stabilization – digestion

Anaerobic stabilization, well known as digestion, according to ONYECHE, T. I. (1999), p. 38 “(...) is a microbiological process in which organic material is broken down by action of micro-organisms in the absence of air” (oxygen). This biological process consists of three phases. In the first phase, hydrolysis, high molecular compounds are degraded into easily biodegradable compounds (monomere, like aminoacids, glucose, fatty acids) and solved in water. During the second phase, acid-producing bacteria transform the dissolved compounds to organic acids (butyr acid and propionic acid), alcohol, hydrogen and carbon dioxide, which is termed as acidification. Eventually, the acetogenic phase and methane phase interact in a symbiotic process. Acetogenic bacteria start to convert compounds into acetic acids thereafter the methane bacteria use these acids to produce the methane gas. [INVENT (2009), p. 189] These processes are presented in simplified way in Figure 5-5 below.
In anaerobic processes, the energy is gained from the system. Hence, carbon is incompletely oxidized and two-third of the produced biogas contains methane. [ONYECHE, T. I. (1999), p. 38-39] This biological process converts organic matter into a mixture of gas which can be used energetically. The major components are methane, carbon dioxide and traces of other substituent’s (Table 5-2).

**Table 5-2: Average composition of biogas by KALTSCHMITT [INVENT (2009), p. 188]**

<table>
<thead>
<tr>
<th>Component</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane (CH₄)</td>
<td>50-75 Vol.-%</td>
</tr>
<tr>
<td>Carbon dioxide (CO₂)</td>
<td>25-45 Vol.-%</td>
</tr>
<tr>
<td>Water (H₂O)</td>
<td>2-7 Vol.-% (20-40 °C)</td>
</tr>
<tr>
<td>Sulfide hydrogen (H₂S)</td>
<td>20-20.000 ppm</td>
</tr>
<tr>
<td>Nitrogen (N₂)</td>
<td>&lt; 2 Vol.-%</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td>&lt; 2 Vol.-%</td>
</tr>
<tr>
<td>Hydrogen (H₂)</td>
<td>&lt; 1 Vol.-%</td>
</tr>
</tbody>
</table>

Anaerobic treatment of sludge has gained rising acceptance during the last years because of its advantages compared with compost systems (aerobic). [WHEATLEY, A. (1991), p. 1-42] The typical proceeding methods can be divided into three different main process temperature as already explained further up (5.2.1). Psychrophilic processing digesters have been rarely applied because of long-term retention. Most common is the mesophilic utilization for digestion facilities. Thermophilic sludge still emits strong odours and is hard to dewater. To optimize the biological processes, two-step digestion can be utilized. This has positive effects on the biodegradation rate, gas yield and retention time. [THOMÉ-KOZMIENSKY (1998), p. 144] The Table 5-3 recommends typical design features for sewage sludge applied digesters.
Table 5-3: Dimensioning recommendations [THOMÉ-KOZMIENSKY (1998), p. 215]

<table>
<thead>
<tr>
<th>Theoretical retention time [d]</th>
<th>Applied load [kg oTS /m³·d]</th>
<th>Temperature [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-15</td>
<td>2.5-4.0</td>
<td>mesophile</td>
</tr>
<tr>
<td>15-20</td>
<td>1.7-2.5</td>
<td>mesophile</td>
</tr>
<tr>
<td>20</td>
<td>2.5-3.0</td>
<td>mesophile</td>
</tr>
<tr>
<td>12-15</td>
<td>3.0-4.0</td>
<td>mesophile</td>
</tr>
<tr>
<td>25</td>
<td>2.2</td>
<td>mesophile</td>
</tr>
<tr>
<td>15</td>
<td>6.7</td>
<td>mesophile</td>
</tr>
</tbody>
</table>

Experience and available literature also indicate that anaerobic systems are not simple to adjust, operate and maintain during long period of time. [ONYECHE, T. I. (1999), p. 38] Anaerobic treatment plants are used in many cases due to the low processing costs and proving an energy contained gas. High construction effort, great sensibility towards toxic ingredients and temperature have effected digestion processes adversely. [THOMÉ-KOZMIENSKY (1998), p. 144] In conclusion, Table 5-4 summarizes features of different types of biogas plants for sludge substrates.

Table 5-4: Features of different types of biogas plants for sludge substrates [INVENT (2009), p. 188]

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS-content of substrate</td>
<td>Dry fermentation (TS from 15 to 65%),</td>
</tr>
<tr>
<td></td>
<td>Wet fermentation (TS up to 15%),</td>
</tr>
<tr>
<td></td>
<td>Anaerobic wastewater treatment (for wastewater)</td>
</tr>
<tr>
<td>Type and source of substrate</td>
<td>Agricultural mono-fermentation plants</td>
</tr>
<tr>
<td></td>
<td>Co-fermentation plants</td>
</tr>
<tr>
<td></td>
<td>Organic waste fermentation plants</td>
</tr>
<tr>
<td></td>
<td>Wastewater digestion</td>
</tr>
<tr>
<td>Temperature of process</td>
<td>Psychrophile</td>
</tr>
<tr>
<td></td>
<td>Mesophile</td>
</tr>
<tr>
<td></td>
<td>Thermophile</td>
</tr>
<tr>
<td>Charging clearance</td>
<td>Batch</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
</tr>
<tr>
<td></td>
<td>Semi continuous</td>
</tr>
<tr>
<td></td>
<td>Quasi continuous</td>
</tr>
<tr>
<td>Method implementation</td>
<td>Single-stage: All degradation stages simultaneous</td>
</tr>
<tr>
<td></td>
<td>Two-stage: Separation of hydrolysis</td>
</tr>
<tr>
<td></td>
<td>Multi-stage: Separation of hydrolysis and formation of acid</td>
</tr>
<tr>
<td>Principle of mixture</td>
<td>Mechanical: - propeller shafts</td>
</tr>
<tr>
<td></td>
<td>Pneumatic: - gas injection</td>
</tr>
<tr>
<td></td>
<td>Hydraulic: - pumps</td>
</tr>
</tbody>
</table>
5.2.3.4 Enhancement of stabilization

Two-step stabilization can be applied to enhance rate and extent of the natural reaction. Therefore, the first step makes use of primary biological degradation processes, while the second reactor can work in optimal methanogenic conditions (e.g. Table 5-4). Add-on enzymes can accelerate both anaerobic and aerobic methods. [THOMÉ-KOZMIENSKY (1998), p. 144]

5.2.4 Disinfection

The term of disinfection summarizes all applications which intend to eliminate or delimitate the epidemiological pathogens, for example bacteria, viruses, protozoans and eggs of parasites. Sewage sludge especially raw, primary and secondary sludge manifest a high potential of pathogens. Digested or stabilized sludge features less potential of pathogens than raw sludge. Due to the agricultural re-uses, the sewage sludge requires disinfection. [THOMÉ-KOZMIENSKY (1998), p. 144-145] Anyhow, disinfected sludge “cannot be considered as sterile”. [DICHTL, N. (2011), p. 14] Covering all measures to eliminate pathogens and also to prevent their reproduction are the main objectives to sustain an uninfected sludge product. [DICHTL, N. (2011), p. 14] Not all treatment methods are explained in detail. The important variants are calcium hydroxide treatment (limestone), aerobic-thermophile stabilization, dual biological stabilization, sludge pasteurization and others. [THOMÉ-KOZMIENSKY (1998), p. 145-147] Well adjusted treatment (stabilization - anaerobic/ aerobic) can cover and include required disinfection processes. [THOMÉ-KOZMIENSKY (1998), p. 142-145]

5.2.5 Removal of water

In general, the water content of sludge varies between 99.5 to 93 % depending on the used wastewater treatment system. This characteristic is one of the main influencing factors for the volume and consistence of sludge, as already represented in 3.1.4.1.1. In some cases, a reduction of the water amount can affect a volume reduction. For all these processes, energy and time are necessary. Therefore, water needs to be removed only when explicitly formulated in the concept (treatment and disposal of the sludge). Hence, frequency tuning is required for optimizing the energy consumption and this has to be well-adjusted. [THOMÉ-KOZMIENSKY (1998), p. 142-145]
5.2.5.1 Thickening and stacking

Thickening is a separation of water from sludge suspension with using of the existing gravity force, as seen in Figure 5-6. With thickener, depending on the characteristics of the sludge, water can be reduced to a TS content range of 4 to 7 %. Stabilized sludge can improve the efficiency of thickening proceedings and increase the TS content of the sludge. Thus, it is highly recommended to utilize these aggregates after the stabilization method process. Typical procedures for dewatering sludge are settlement (settlement cone, settlement tank), filtration and flotation by pressure drop. [THOMÉ-KOZMIENSKY (1998), p. 148] The next practical measure is to temporarily store the sludge (stacking of sludge). Stabilized and thickened sludge should be stacked for proper management and organization. During the stacking, scum layers should be avoided and broken down. It is important that the stored sludge should be homogeneously mixed and stays pumpable during the stacking process. Moreover, stacking provides an improved flexibility and prevents failures during further treatment and disposal paths. Continuous mass flow can be switched to discontinuous single processes and adopted portions can be provided. Thereby, proper interactions to other re-uses or drying methods, which are only possible during some periods, can be guaranteed. [THOMÉ-KOZMIENSKY (1998), p. 149]

5.2.5.2 Dewatering

The capability of dewatering operation depends on the properties of the sludge, on the respective dewatering process and operation conditions. The properties of sludge largely vary, explained by [THOMÉ-KOZMIENSKY (1998), p. 149], depending on several impacts, for example place of generation, ratio of commercial and industrial sludge, pollutant concentration, retention time in settlement tanks and used stabilization process.
5.2.5.3  Natural dewatering

The natural dewatering process is very attractive for Southeast Asian countries because of its simple install technology with low or without energy input and only a few required operation and maintenance skills. [ULRICH, A. et al. (2009), p. 34] Natural dewatering can be smoothly utilized in the climatic condition of Southeast Asia. Some of these technologies have been well tested, for instance in Indonesia, Thailand or Vietnam. Only stabilized sludge (aerobe/anaerobe) should be naturally dewatered. [THOMÉ-KOZMIENSKY (1998), p. 149] Dewatering and treatment of non-stabilized sludge in the open air lead to emissions of bad odours and nuisance from flies [ULRICH, A. et al. (2009), p. 309] For all treatment methods, the drained leachate has to be collected and traced back to the wastewater treatment facility. [THOMÉ-KOZMIENSKY (1998), p. 149]

In drying beds (Figure 5-7) or sludge drying lagoons, sludge settles at the ground. Gravitation and evaporation can dewater the sludge up to 35 % of its solid content. [THOMÉ-KOZMIENSKY (1998), p. 149] This technical application has been well practiced in Da Lat (Figure 5-7), Banda Aceh and near Yogyakarta (both Indonesia). Due to its greenhouse roof it is operating also during the raining season. [ULRICH, A. et al. (2009), p. 317]

![Figure 5-7: Sludge drying beds in Vietnam, Da Lat](Photo: Pogade, F. (2009), in Da Lat)
In former times, **conventional sand drying beds** have been used more and frequently in Germany. Altogether, it has been pointed out in Germany that these methods are not suitable for large scale treatment nowadays. Reasons for this are large place requirements, long dewatering time, climatic conditions and limitations of dewatering. [THOMÉ-KOZMIENSKY (1998), p. 149]

Another natural based process is the **sludge drying bed** (Figure 5-8) with reeds or grass. As reported, this method can be applied particularly in small scale approaches (up to 30’000 PE). [GÖDECKE, D. (2004), p. 1-12] The end product indicates a high humus quality. Removal of the matter needs to be done in 7 to 10 years periods. It is recommend to use this cleared material in composting plants or directly as fertilizer. [GÖDECKE, D. (2004), p. 1-12] The design for this treatment method is shown in Figure 5-8.

![Wind action](image.png)

**Figure 5-8: Scheme- reeds planed sludge drying beds** [Heinss, U. et al. (1998), p. 5]

The essential size ratio makes the approach inapplicable for large scale treatment, but in small facilities sludge drying beds with reed implicate real advantages. Those advantages are for instance little energy consumption, small treatment effort, continuous complex handling and very well stabilized humus (fertilizer) which can be re-used in agriculture or for landscape measures. [GÖDECKE, D. (2004), p. 6-11]

states in his report, “(...) that the ‘SolarMix’ process is extremely effective at both stabilising the biosolids and dramatically reducing the volume and mass of the material to be transported and reused.” In the future, the dryer’s efficiency and drying time are necessary to improve, [ZWEIFEL, H. et al. (2001), p. 459-463].

![Figure 5-9: Solar drying green house](image)

Different practical pilot researches have proved that this system works very well from an economical and ecological point of view considering the very low input of energy and the small technical and mechanical effort. It has been approved to be more climate-friendly than conservative technologies. Solar drying is applicable when the solar radiation reaches 300 W/m² and the relative air-humidity falls below approximately 80 %. [WITTMAIER, M. et. al. (2006), p. 1-2] Evidentiary, sludge dries faster in summer than in winter. This fact has to be considered for the treatment and capacity design. Solar sludge drying technology is utilized in plants designed until 300’000 PE. [WITTMAIER, M. et al. (2006), p. 1-2]

5.2.5.4  Mechanical dewatering

The following mechanical dewatering elements can operate with energy input:

- Chamber filter press,
- Belt filter press and screen filter press,
- Centrifuge and decanter

The utilization of sludge conditioner influences the dewatering rate positively. Polymers should be deployed for increasing dewatering efficiency. It pondered about this technical approach if place requirements constitute the major role for the decision.
For smaller facilities, mobile dewatering methods can be considered for an economical point of view. [THOMÉ-KOZMIENSKY (1998), p. 150-151]

5.2.6 Drying

Drying can accomplish higher TS values than dewatering. These drying processes can be assisted by vaporization and evaporation. The total solid content can provide values from 60 up to 95 % of a total solid content. The outcomes are above all volume reduction for further treatment or disposal paths, minimization of transportation costs and a value added product (well-stabilized). Drying manifests a very cost-intensive process. [THOMÉ-KOZMIENSKY (1998), p. 151-153] Convection drying, contact drying, combined dewatering and drying process are characterized as typical drying features. Due to immensely high costs of operation, these methods can be expected to extension methods for sludge treatment in large-scale approaches for the future. [THOMÉ-KOZMIENSKY (1998), p. 152-153] The current situation and conditions in Vietnam require a provision with easily applicable treatment techniques and financeable methods.

5.2.7 Agricultural uses and landscape measures

Sewage sludge can be utilized in different states and ways, e.g. wet, dewatered, dried, composted or as fertilizer. [THOMÉ-KOZMIENSKY (1998), p. 153] Furthermore, to get an overview of the positive and negative effects of sludge, the following chart Figure 5-10 illustrates the nutrients and pollutants in the sludge.

---

**Figure 5-10: Balance of nutrients and pollutants** [DICHTL, N. (2011), p. 21]
Re-using nutrients in the cycle of matter, stabilized sewage sludge can be utilized in agriculture or for landscape measure in abidance with the law formulated standards. This is urgently needed to guarantee an adherence of safety, environmental compliance and the prevention of health risks. [THOMÉ-KOZMIENSKY (1998), p. 152-153] Considering all the information based on scientific literature and publications, the application of sewage sludge in agriculture is a controversially discussed subject matter. The final result is that the application of sewage sludge in agriculture effectuates a contamination/pollution of the soil. [THOMÉ-KOZMIENSKY (2001)] A documented fact in waste management is that waste material can be re-used; taking into account the pre-condition that it is utilized in a non-dangerous or environmental-friendly way. It has been scientifically proven that the re-use of sludge does not confirm to these basic principles. The statement has been confirmed by scientific-based arguments many times. [THOMÉ-KOZMIENSKY (1998), p. 152-153]

Figure 5-11: SNV slurry fertilizing [abdphoto.net]

5.2.8 Biological re-uses

Biological re-use explains a process which degrades the organic matter of stabilized sludge. Besides, volume and organic matter can be reduced even more with the biological processes. The used sludge has to be environmental compatible so that the end-product can be utilized conform to legal conditions. Established systems are most notable composting and fermentation. Both of these processes use the organic fraction of municipal waste collection. This should not be mixed up with wet composting (5.2.3.2) and digestion (5.2.3.3). [THOMÉ-KOZMIENSKY (1998), p. 153]
5.2.8.1 Composting with organic wastes

THOMÉ-KOZMIENSKY defines in his book, that composting “(...) is a biological reduction and converting process of organic material, in presence of oxygen, to the major products, water, carbon dioxide and humid acid residues, which is called compost.”

Composting can proceed at different temperature levels, such as psychrophile, mesophile, thermophile, as depicted in Figure 5-12. The three major treatment methods of composting are static, dynamic and semi-dynamic rotting process.

![Temperature ranges of microorganisms (composting) (INVENT (2009), p. 184)](image)

The created compost product can be applied as soil conditioner, humus source and material for reclamation or landscape measures, regarding to the given compost quality standards (pollutants limits). However, the fertilizing effect through humus is limited, the market for humus is low-developed and there still is only a small market demand. [THOMÉ-KOZMIENSKY (1998), p. 155] Vietnamese humus is of very poor quality (e.g. Kieu Ky (Figure 5-13) and Cau Dien composting site) and the current market price for one Mg humus [URENCO HANOI] is about 60.000 Dong (approx. 2 €).

Mono-sewage sludge composting could not sustain itself as a treatment method. So far it is only applied in smaller scaled plants through. The advantages of this method are range on the possible application of the compost, and further stabilization and dewatering of the sludge. Moreover, the compost can be stored more easily. On the other hand, there are some disadvantages like disturbing odour, produced leachates and high mechanical and processing efforts. [THOMÉ-KOZMIENSKY (1998), p. 155]

---

High treatment costs of sludge composting plants which amount to approximately 100-250 € per Mg\textsubscript{TS} compared with the low market price on composting products recently turn out to be very unprofitable. [THOMÉ-KOZMIENSKY (1998), p. 155]

The list of composting sites in Vietnam is outlined in the following Table 5-5.

Table 5-5: Composting plants in Vietnam [INVENT (2009), p. 285]

<table>
<thead>
<tr>
<th>Location of the plant</th>
<th>Capacity [Mg/d]</th>
<th>Start of operating</th>
<th>Organic waste source</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cau Dien</td>
<td>140</td>
<td>1992, expanded 2002</td>
<td>waste form market, streets, restaurants, public septage</td>
<td>operational, 3 products selling; price of VND 800, 1200 and 2000/kg</td>
</tr>
<tr>
<td>Kieu Ky</td>
<td>150</td>
<td>2009</td>
<td>separated organic waste Gia Lam district (6 communes), non separated municipally waste</td>
<td>operational, free product, operation problems</td>
</tr>
<tr>
<td>Nam Dinh City</td>
<td>250</td>
<td>2003</td>
<td>non-separated municipal waste</td>
<td>operational, free product provided (for farmer)</td>
</tr>
<tr>
<td>Phuc Khanh, Thai Binh</td>
<td>75</td>
<td>2001</td>
<td>unidentified</td>
<td>operational</td>
</tr>
<tr>
<td>Viet Tri, Phu Tho</td>
<td>240</td>
<td>1998</td>
<td>unidentified</td>
<td>operational, 3 products selling; price of VND 200, 250 and 900/kg</td>
</tr>
<tr>
<td>Hoc Mon, Ho Chi Minh</td>
<td>240</td>
<td>1982, closed 1991</td>
<td>non-separated municipal waste</td>
<td>closed down due to difficulties in selling the product</td>
</tr>
<tr>
<td>Trang Cat, Hai Phong</td>
<td>50</td>
<td>2004</td>
<td>mud, matters from dredged canals, non-separated municipal waste</td>
<td>operational, test period</td>
</tr>
<tr>
<td>Ninh Thuan</td>
<td>100</td>
<td>1998</td>
<td>non-separated municipal waste</td>
<td>operational</td>
</tr>
<tr>
<td>Thuy Phuoc, Hue City</td>
<td>159</td>
<td>2004</td>
<td>non-separated municipal waste</td>
<td>operational, 3 products selling; price of VND 1100 to coffee and rubber farmers</td>
</tr>
</tbody>
</table>
5.2.8.2 Fermentation with organic wastes

In absence of oxygen, biogas, digestate and wastewater are produced in the course of fermentation processes. All products require further treatment processes. The addition of organic waste results in an increase of the biogas yield. The produced gas should be dried and prepared through removal of sulphur and other trace substances. Afterwards the cleaned gas should be the energy source for a block heating station for energy production. [THOMÉ-KOZMIENSKY (1998), p. 155-156] The technique equipments are similar to the described methods in chapter (5.2.3.3). Realizing a well-functioning operation and safe proceedings trained personnel are demanded. Advantages of this method can be seen in the low size ratio, its compacted construction, low odour emission, homogenously produced gas (fuel), and energy production. The produced heat and energy can cover process input energy and even delivers extra energy. In Germany, treatment costs vary and amount to between 100-200 € per Mg Ts. Due to the addition of organic waste, an increasing load of wastewaters and rising digestate amounts have been determined. [THOMÉ-KOZMIENSKY (1998), p. 155-156]

5.2.9 Thermal disposal (energy recovery)

Immense mass and volume reduction, energy and heat production, elimination of the pollutants of the cycle of matter and accumulation of pollutants in inert residues are the main reasons why incineration should be used. On the other hand there are also some disadvantages like, high investment costs, high operational effort, difficulties in operation control. [THOMÉ-KOZMIENSKY (1998), p. 156-159] Altogether, incineration treatment costs are approximate 300-500€ per Mg Ts. [THOMÉ-KOZMIENSKY (1998), p. 158] Obviously, sewage sludge in Vietnam offers lower heating values than European sewage sludge. In addition, scientific researches are necessary to figure out if exclusive incineration of Vietnamese sludge is possible. Exeunt \( H_\circ \approx 5500 \text{ kJ/kg} \text{ TS} \), sludge burns without co-firing.

- Mono-incineration

Mono-incineration of waste is practiced in Europe with over 50 years of experiences. A major incineration proceeding for sewage sludge is fluidized bed combustion. [THOMÉ-KOZMIENSKY (1998), p. 156] Mono-incineration of sludge with fluidized beds has the most practical applications (large-scale). [FIW (2003), p. 1/3] The fluidized bed combustion is divided into three technical methods, static, rotating and circulating fluidized bed combustion. In general, a single combustion process operates with a temperature of 850° C, with a minimal waste retention time of 2 sec inside combustion
chamber and with a minimum oxygen concentration of 6 vol.% in the flue gas. Depending on the concentration of the organic matter, water and the heating value, sludge has to be dewatered and dried up to required point where it combusts well. Combustion residues (bed ash, flue gas, filter dust and slack ash) have to be treated and disposed of in an environmentally-friendly and safe way. Occasionally, a multiple-hearth incinerator provides a safe combustion process for sludge and can be utilized for drying sludge. [THOMÉ-KOZMIENSKY (1998), p. 157]

- Co-incineration

Co-incineration works with both dried and dewatered sludge. The specific quantity of sludge which has to be added mainly depends on the water content. In general, household wastes are mixed up with sludge. The added combustion rate of sludge is limited up to 20% because of its decrease influence on the heating value and an abatement of combustible character. [THOMÉ-KOZMIENSKY (1998), p. 159] The co-incineration presents the highest application potential in practice. [FIW (2003), p. 1/3]

Therefore the blending needs to be as homogenous as possible. The input of sewage sludge can be carried out through dust injection in the combustion chamber or mixing of sludge with solid waste in the waste bunker or through a cone input. Co-combustion with sewage sludge demands an explicit residues treatment even to larger extent than that of the normal thermal waste incineration. Therefore, it needs a higher demand of flue gas cleaning actions. Bed ash, flue gas, filter dust and slack are produced residues and require further treatment and disposal. [THOMÉ-KOZMIENSKY (1998), p. 159] In Figure 5-14, the basic units of an ordinary solid waste incineration plant is presented.

![Diagram of combustion plant](image_url)

**Figure 5-14: Principle of a combustion plant by IGELBÜSCHER [INVENT (2009), p. 162]**
Gasification, degasification, pyrolysis, melting, combined processes and wet-oxidation are names of other available combustion methods. Detailed information according to these methods can be found in the book of THOMÉ-KOZMIENSKY (1998) on page 156-160.

5.2.10  Land-filling

The opportunity of land-filling sludge delivers one disposal path. Landfills are subdivided into several types, mono- and municipal waste disposal sites are suitable for sewage sludge. Disposal of wastes is a far more complex subject area than it appears at a first glance. Standards for landfill construction and disposal of a material have to be adhered. Sewage sludge is difficult to landfill. The reasons for this lie in its highly complex material characteristics. Therefore, pre-treatment steps for sewage sludge are obligated. Otherwise, massive problems with production of leachates, odours and landfill gas or instability of the landfill body can occur. [THOMÉ-KOZMIENSKY (1998), p. 159]

Professor BILITEWSKI teaches in the basic lectures of waste management that each landfill site is considered to be an immense risk to become a decontaminated site. In particular for sludge, to guarantee stability of the landfill body, the water content and organic matter needs to be reduced and pH-values adjusted. In a short-term view, land-filling might be the cheapest way to dispose of sewage sludge, but in a long terms view it is certainly the most costly way of disposal. [THOMÉ-KOZMIENSKY (1998), p. 159]

The chief reasons for the turning away from landfills are "...(.) scarce landfill sites, leachate leaks through the landfill liners contaminating the groundwater quality in the surrounding areas, regulatory drivers, methane (CH₄) emissions from biodegradable waste, contributing to climate change and local hazards such as fire risk, non-sustainable use of land and odour." [INVENT (2009), p. 37]

In the following, the figures summarize different treatment and re-use or disposal paths in Figure 5-15 and Figure 5-16.
SLUDGE TREATMENT AND DISPOSAL OPTIONS

Figure 5-15: Disposal paths for sewage sludge [THOMÉ-KOZMIENSKY (1998), p. 4]

Figure 5-16: Processing chain of sludge treatment and disposal [THOMÉ-KOZMIENSKY (1998), p. 162]
6 SEWAGE SLUDGE MANAGEMENT CONCEPT

All the past chapters are the basis of the sludge management concept. Creating an integrated treatment and disposal concept for sewage sludge in Vietnam, the background and detailed information about produced sludge amount and its characteristics, place of generation, climate, culture, financial resource, legal framework, available techniques and the processing elements (etc.) are required.

Reduction, re-use and recycling, recovery and disposal are the major components of the waste management strategy. However, this sewage sludge concept has the main objective to achieve a material cycle society. Reduction is the best and most effective usage of a matter with small consumption of resource and the smallest amount of waste discharged. Re-use means the discharged products can be utilized again in the same or in another manner. Recycling refers to upgrading waste into new products (up-cycling) and can be applied in two forms, recycling at source of the production or recycling of waste material. Recovery means using the waste to achieve a beneficial outcome. If recovery is not possible, disposal is realized and waste is discharged of in a safe and environmentally sound manner (Figure 6-1).

Figure 6-1: Hierarchy of waste management [INVENT (2009), p. 28]
6.1 AVOIDANCE

The prime target of waste management is to reduce the generation of waste and to optimize the organization of waste treatment and disposal. The strategy for sludge management should first aim to reduce the production (quantity) as well as the pollutant concentration (quality) at the level of the producer.

Waste prevention and promoting effective recycling methods are major targets to reduce the negative impact of waste on the environment. The recycling approach provides that every item of waste is not seen only as a source of pollution to be reduced, but also as a potential resource to be exploited. The order of preferable waste activities ranges from avoidance to disposal and is outlined in Figure 6-1. In the case of sewage sludge, the possibilities and activities to avoid sludge production are very limited. The discharge of industrial and commercial wastewater can be reduced due to legal and technical measures, controls and by controlled-monitoring systems, observed by the state authorities. Therefore, a stronger legal force is required to implement the "polluter pays" principle in Vietnam and then the costs of the clean-up will be paid by the company that caused the damage. With these measures, mainly the concentration of pollutants can be minimized and observed.

For epidemiological photogenes and other fungi from hospitals, slaughterhouses or meat processing companies, these measures cannot be applied successfully. The municipal sewage sludge amount in Vietnam can only be reduced through minimizations of illegal solids and solid waste inputs in sewerage and through a better adjustment of the wastewater treatment plants. Further reduction can be reached through sludge treatment.

6.2 TREATMENT

In the developed concepts, the entire treatment process considers that the produced material of the sewage sludge treatment plants should be a re-usable material which can be utilized in agriculture. Sewage sludge is used under the basic premise that only selected areas in agriculture are utilized and the quantity and quality of the sludge should not exceed the standards of the guideline (draft).

Generally, solid waste management achieves the principles of avoidance and re-use successfully, whereas the management of sewage sludge can just partly realizes these principles during the treatment, re-use and disposal processes. Either valuable materials (C, N, P) are utilized and pollutants are emitted (agricultural re-
use), or pollutants are kept away from ecological systems and the valuable materials are destroyed at the same time (waste incineration). In fact, the current situation needs to develop new ways and innovative concepts for sewage sludge management in the future.

Normally, the sewage sludge of DWWTPs and septic tanks is produced off-site and this sludge has to be transported to sludge treatment plants. The location of the facility has to be well-selected to reduce the transportation costs. Moreover, emitted inevitable odours and noise during the operation process should be considered. The transportation route should not exceed a distance of 50 km (maximum). To design a semi-central or central sludge treatment plant is much more ecological and economically worthwhile. Especially, already existing WWTPs should be considered as a location first, because of produced wastewater during the sewage sludge treatment processes and the produced sewage sludge of the WWTP. Otherwise sewerage or decentralized wastewater treatment plants have to be constructed. The sewage sludge treatment solution should indicate the following parameters to be suitable in practice:

- Minimum of investment, operation and maintenance costs
- Small land requirements
- Enable to fulfil the legal requirements
- In the long run, simple to operate with small elementary maintenance efforts, skills required for operation and supervision as basic as possible
- Low estimated risk of failures
- Low-tech solution, relative-easy in handling, simple understanding for skilled locals
- Proven technology and know-how and construction with local material / worker
- Durable construction and proceeding elements
- Universally applicable in Vietnam for different inputs and varying climatic situations
- Low energy demand (low pumping effort, use of gravity, hydraulic pressure, slope)
- Achievable consistency of solids, safe hygienic quality of solids, required quality of liquid effluent (QCVN)
- Cost effective end-products (biogas, energy, fertilizers, compost, biosolids etc.)
SEWAGE SLUDGE MANAGEMENT CONCEPT

- Fully safeguarded sludge management (odour, leachate, without human health risks)

The concepts should preferably be applied for sewage sludge of municipal wastewater treatment systems in urban areas in Vietnam. In detail, these systems can be for instance centralized wastewater treatment plants, decentralized wastewater treatment plants, septic tanks, sewerage and wastewater channel residues, or similar ones.

6.2.1 Proposed treatment concept

The proposed concepts in the current study meet the requirements in the above outlined key points at the best possible rate. Subsequently, two treatment options are proposed. Both options include general processing steps, sludge reception, preliminary treatment, stabilization, dewatering/drying and re-use/disposal.

The differences of the concepts lie mainly in the designed sludge capacities of each treatment method. The **small-scale** treatment facilities operate up to 30’000 inhabitants and the other concept (**medium/large-scale**) starts at the capacity of 30’000 inhabitants. The received sludge will undergo different preliminary processes (bar screens, grease trap with integrated grid chamber). The pre-treated sludge will be stabilized through an anaerobic digestion process and produced biogas will be used effectively to generate power and heat. After that, the supernatant liquor is cleaned in a separated WWTP and then the digestate (sludge) will be transported to the gravity thickeners. Thereafter the thickened sludge is discharged into sludge yards for one month before it is finally re-used or disposed of (in 6.3).

6.2.1.1 Small-scale concept

The sludge will be transported by special tankers and dropped at the entrance of the sludge treatment plant. In the preliminary treatment section, screenings and other solid particles will be kept back by bars and dropped into a waste container. Periodically, the screenings in the waste container will be transported to the necessary treatment or disposal facility. In accordance with Figure 3-5, screenings can be treated, re-used or disposed of. Thereafter, the sludge liquor will be flowed to the grease trap and integrated grid camper. The removed grid will be collected in a container and
transported occasionally as the situation demands. Further, grid should be treated as recommend in Figure 3-4.

Collected grease will be used additionally together with the sludge matter in the next treatment step, the anaerobic digestion, to increase the gas yield. The double-stage digestion process will treat the input material under mesophilic temperature condition. Approximately 20 days retention time are planned. The digestate is transferred to the thickening element and the supernatant will be collected and transported to the WWTP or DWWTP. Thereafter, at the gravity thickener, produced effluent underflow will run off in pipelines (with hydraulic pressure and natural slope) to the Plexiglas roofed sludge drying beds with reeds.

The collected thickened effluent, the supernatants and the leachate from the sludge drying bed will discharge to the WWTP. The overall aim is to produce an odourless and well mineralized sludge as an end product. The mineralized matter can be dried after removal again. Normally, these products do not require any further treatment steps, but to upgrade the quality of the matter, additional composting steps can be done. The removal of the mineralized matter should be done when the sludge level exceeds one meter. Generally, this required step should be done in periods of 7 to 10 years.

In particularly exceptional cases, in which larger amounts of sludge cannot be transported to a treatment facility, sludge drying bed with reeds, sand drying beds or sludge dewatering bags can be installed directly next to the DWTTP. Therefore, the leachate drainage should be collected and transported to the DWWTP and the further dried sludge should be re-used or disposed of.

Figure 6-2: Small-scale concept
6.2.1.2 Medium/large-scale concept

The sludge matter will be transported by special tankers and dropped at the entrance of the preliminary sludge treatment. Further, in the preliminary treatment section, screenings and other solid particles will be kept back by bars and dropped into a waste container. Periodically, the screenings in the waste container will be transported to the necessary treatment or disposal facility. According to Figure 3-5, screenings can be treated, re-used or disposed of. Thereafter, the sludge liquor will be run off to the grease trap and integrated grid camper. The removed grid will be collected in a container and transported to treatment systems occasionally as the situation demands. Further, grid should be treated as recommended in Figure 3-4.

In order to reduce further sludge volume and amount, the medium/large-scale concept has two integrated sludge thickeners. After settling of the sludge, supernatant will be treated in a WWTP and the underflow of the thickener (thickened sludge) will be transferred to the digester feeding system. This system will control the digesting process and provide an ordered digester feed (continuous/discontinuous).

Collected grease will be used additionally together with the sludge matter in the next treatment step, the anaerobic digestion, to increase the gas yield. Regarding the medium or large sludge option, the system should be applied in a single or double lined two-stage mesophilic digesting system. Shortly after the end of the digestion, the digestedate is transferred to the second thickener. Thereafter, the thickened sludge is discharged with hydraulic pressure and natural slope to roofed sludge drying beds with drainage system. In this section the sludge is stored for about one month. Sludge drying results depend on season and location. In general, climatic conditions in Vietnam (also North-Vietnam) guarantee ∼40 % dry substance content in all seasons. Roofs in general are important for all areas, especially these areas affected by the rainy season. The dried sludge matter should be removed periodically and disposed of. If composting is not possible, in this step the dried sludge can also be re-used or disposed of directly. The thickened effluent water, the digester supernatant and the leachate drainage from the sludge drying bed will be collected and transported to the WWTP or DWWTP. The aim of this concept is the production of a marketable compost product through a rotting process under a roofed yard. The rottings should be stored and processed for approximately one month. Temporarily, the rotting matter has to be circulated and mixed, which refreshes the oxygen content and guarantees uniform moisture. Thereafter, the compost can be utilized as presented in 6.3.
6.3 RE-USE OR DISPOSAL

Basically, to safeguard sludge disposal paths sludge can be re-used or disposed of with the outlined methods: in agriculture, for landscaped measures, in thermal waste disposal plants, in landfill sites and for other or alternative disposal paths. In the long run, it should be focused on a preferred disposal path of sewage sludge with thermal waste incinerators. In the short and medium term, the proposed concepts recommend the utilization of the produced matter in agricultural or for landscape measures. Reasons for this lie on the deficient of waste incinerations plants, high-tech operation needs, limited investment capital for new investments, high treatment cost, exerted pressure of sludge management in urban areas, immediate demand and an adequate way to stop illegal waste dumping as well. Therefore, each sludge has to be approved for harmful effects throughout the use of sewage sludge in agriculture. Furthermore, a draft of a guideline has been worked out to ensure a safe and environmentally sound utilization in selected areas of agriculture.

Applications for Vietnam can be seen in agricultural uses (e.g. rubber, tree nursery, forest, etc.) or horticultural uses (commercial/ private); forestry uses; re-cultivation of landfills; re-cultivation of mining areas; landscaped measuring; greenings of streets/roads, parks or cities; reduction of nitrogen washout and for reduction of soil erosion in particular in the North. Whether these usages are limited or prohibited, the matter has to be disposed of in a safe way.
6.3.1 Small-scale concept

The amounts of sludge are very low and are generated in periods of around 7 to 10 years. Depending on the region where it is generated and the characteristics of the stabilized matter, it can be used (regulated/controlled) as fertilizer in agriculture as well as in horticulture or for landscaped measures.

In particularly exceptional cases such as smaller DWWTPs in rural areas, for instance, the stabilised sludge can be spread directly on flower beds as fertilizer. The slightly foul odours will be accepted in most cases. Sludge analysis can ensure non-harmful effects.

6.3.2 Medium- and large-scale concept

The produced compost product needs to be analysed and checked before it is used for the first time. Thereafter, composts can be used as soil conditioner, fertilizer or biosolid in agriculture, as mentioned in the description above. Compost as a fertilizer can be considered as an alternative to expensive mineral fertilizers. All these materials used in agriculture require an all-embracing regulation (uses of sewage sludge in agriculture) and need to be implemented. In the next chapter a draft of a guideline will be developed. However, the guideline is a draft to cover this range and tries to close the legal loopholes supportively.

Intensive marketing efforts are essential to achieve a successful commercialization of the biosolids produced from sewage sludge treatment plants. Good marketing is very important for the successful commercialization. Close collaboration with agricultural service providers and cooperation partners to test and commercialize the new products is recommended. The compost products need to be introduced because Vietnam’s agriculture requires a high quality organic fertilizer. The compost product is made available throughout the whole year, higher quantities are supplied in January/February and June/July (for rice cultivation). The produced compost needs to be packed in sacks and transported to local agents and cooperatives. The cooperatives are used for initial commercialization. These cooperatives could later act as local agents and inform farmers about the quality of the product.

**Biogas appliances:** In principle, biogas can be used like other fuel gases for households, commercial and industrial purposes. The preferred method is energy production, using of biogas fuelled-engines on-site to cover the sludge treatment energy demand. The gas production rate itself decides which application is most feasible. If the
biogas of treatment system is to be applied for fuel engines, the digester must produce at least 10 m³ per day. For instance, to generate 1 kWh of electricity, about 1 m³ biogas is required. [ESCAP (2007), p. 8-15] Otherwise, biogas can be utilized basically for gas cookers/stoves, lamps or to produce heat with radiant heaters. Table 6-1 below offers advantages and disadvantages for both options compared briefly.

6.4 CONCLUSION

The concept offers an effective performance for different amounts of sewage sludge. The expected hygienic quality of the biosolids and the quality of the liquid effluent achieve the aim of high-rated end products. The drying beds with reeds provide good biosolids treatment with minimal treatment effort, whereas the second option requires post-treatment of biosolids to achieve comparable results. Composting is a satisfactory performance to upgrade the biosolids quality. Thus, the produced compost will obtain the best results (saleable product). Both treatment options use simple and reliable technologies. These options should be able to meet the requirements for operation and maintenance and for the workers skills, too. The concept contains some weaknesses, but the over-all risk of failure is rather limited if minimal operational care and maintenance are observed (disadvantages - Table 6-1).

Table 6-1: Comparison of treatment options

<table>
<thead>
<tr>
<th>Concepts</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1: small-</td>
<td>Simpler operation,</td>
<td>Drying effort depends on weather conditions,</td>
</tr>
<tr>
<td>scale</td>
<td>No chemicals used,</td>
<td>Smaller capacity,</td>
</tr>
<tr>
<td></td>
<td>High dryness doubtful to reach,</td>
<td>Land requirement,</td>
</tr>
<tr>
<td></td>
<td>Odorless biosolids,</td>
<td>Know issues of digestion processes,</td>
</tr>
<tr>
<td></td>
<td>Biogas supplied.</td>
<td>Odour emission during the processes.</td>
</tr>
<tr>
<td></td>
<td>Higher capacity,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No chemicals used,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Higher biogas supply,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High dryness doubtful to reach,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Higher original costs,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Compost produced,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drying effort depends on weather conditions.</td>
<td></td>
</tr>
<tr>
<td>Option 2: large-</td>
<td>Higher technology effort,</td>
<td></td>
</tr>
<tr>
<td>scale</td>
<td>More difficult for service and handling,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drying effort depends on weather conditions.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Know issues of digestion processes,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Land requirement,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Odours emission during the processes.</td>
<td></td>
</tr>
</tbody>
</table>
Both options can be considered as equally appropriate for the conditions prevailing in Vietnam. Construction cost, including land requirements are very similar for the concepts according to the specific sludge amounts. However, estimations for operating costs show considerable differences: the most economic to operate are the first option, but with a larger sludge amount and higher expectation to the produced end-product the second option becomes more economically interesting. The evaluation of the two concepts demonstrates that in all criteria, exist advantages and disadvantages (Table 6-1). As a conclusion it can be stated, that both constructed concepts are using the best treatment technology for the projected quantity and quality of sewage sludge and for the currently prevailing conditions in Vietnam.

In the future, when conditions will change and sludge production rate will increase considerably, it might be possible that other technologies become more interesting. The revision of the treatment strategy after a number of years is recommended.
7 GUIDELINE (DRAFT)

7.1 FORMULATION OF A GUIDANCE DOCUMENT

“Sludge is not permitted to be the jam for our sandwich”, [Dichtl (2011)]. Therefore, the situation in Vietnam requires to be regulated for different re-use and disposal paths of sewage sludge, which shall be fully safeguarded for environmental media. The important fact of the statement of Prof. Dichtl’s is that it can be assumed that sludge can have harmful effects when used in agriculture. Consequently, it should be recommended and encouraged how to utilize sewage sludge to prevent dangerous contacts, especially for the food chain. For a discussion and intensifying awareness in this field, a draft of a guideline “On the protection of the environment, and in particular the soil, when sewage sludge is utilized in selected areas in agriculture” has been produced to serve as a basis for an intensive interchange between the responsible authorities and the WWM project, [GUIDELINE; p. 1]. The objective of this guideline aims “(…) to regulate the utilization of sewage sludge in agriculture in such a pathway as to prevent harmful effects on soil, vegetation, animals and human, while encouraging its correct utilization; (…) Whereas sludge can have valuable agronomic properties and it is therefore justified to encourage its application in agriculture provided it is utilized properly; (…) Whereas the utilization of sludge on fruit and vegetable crops during the growing season, except for fruit-tree crops, must be prohibited;” [GUIDELINE]

Within the draft, the scope is clearly defined (article 2), applicable sludge types are elaborated exactly (article 3 and 4 ), conditions for the utilization are established (article 4) and the amount, rules as well as limits for sewage sludge in agriculture are regulated. Other facts have been outlined in detail, for example exceptional cases (article 5, No. 7 and 8), obligation to produce records (article 9), application plan (article 10), research (article 11) and adjustment of this guideline (article 12). [GUIDELINE]

In the annex, different limits values for concentration of heavy metals in soil and sludge have been listed (Annex I A, B and C). Furthermore, instructions are carried out about how to sample or analyze sludge and soil. (Annex II A and B) [GUIDELINE] This guideline doesn’t claim to be complete for circulation rather it should be understood as a signal for ministries to rise awareness for efficient sludge management and to start the discussions with several experts and to have a better communication between the WWM project and the relative authorities. The discussion about the guideline and results of the recent study could not be presented or adjusted with responsible ministries.
8 CONCLUSION

In summary, this study pointed out scientific findings for the legal and institutional framework as well as current sludge management practices. Moreover, it provides theoretical information for the concepts, a couple of analysis results and last but not least an integrated concept and guideline (draft).

The most important prerequisite for removing current barriers is that decision-makers at government agencies relevant to manage sewage sludge at all levels need to be willing to make modification to existing institutional structures. Moreover, wastewater tariffs are necessary to recover operation cost for wastewater treatment plants. As a principal conclusion, a lot more effort should be strengthened in terms of heighten public environmental awareness in Vietnam. If the public cannot understand the benefits of the projects the willingness to pay will not increase. At the public, sewage charges have to be implemented and enforced.

As an outcome of the investigation of various sewage sludge types, values of sludge samples in Vietnam have pointed out remarkable differences in the composition compared to typical European sewage sludge. In particular, the organic dry matter and energy content are considerably lower than European sewage sludge values. Nevertheless, final outcomes of heavy metal concentration show significant values. Furthermore, in some cases they exceed the allowable limits of the German ordinance of waste sludge (AbfKlärV). In general, these results can be used as a basis to compare sludge results in Vietnam. In addition, a lot more samples, results and sludge research are required. Further research shall ensure that these results demonstrate representative values for Vietnam’s sewage sludge. As a result, particularly caused by the intensive interactions and cooperation with analytic laboratories, it was determined that some of the Vietnamese laboratories necessitate more training of the personnel. Moreover, a lot more supervision and evaluation of results in terms of sludge analytics is needed.

The research has reached the conclusion that new constructed wastewater treatment plants as well as emptying of septic tanks and upgraded wastewater facilities produce more and more sewage sludge. Due to the increased sludge amount in Vietnam responsibilities will rise to a challenge in terms of the treatment and disposal of sewage sludge in the years to come. For that, sewage sludge management in urban areas in Vietnam requires to be more and more improved. Therefore, in the short term run, sewage sludge amounts need to be reduced with appropriate treatment strategies.
Hence, the developed sludge treatment concept in the paper can help to solve these problems. These treatment plants will transform sewage sludge in a solids fraction with greatly reduced volume and a very low pathogen content, and in a liquid fraction suitable for discharge after a minimal treatment in a wastewater treatment plant.

The developed concept represents integrated options for an appropriate sewage sludge management for the conditions prevailing in Vietnam. Both treatment options use simple and well-engineered technologies. Moreover, all options will produce attractive end-products - biosolids, biogas, heat, light or energy. However, the concept and its operational costs can be considered as economic option for the management of sewage sludge from municipal wastewater treatment systems in urban areas in Vietnam. Furthermore, particular cost study should be done to determinate treatment and investment costs of this concepts in an individual case of application. As a major conclusion it can be stated, that the engineered concepts are using the best treatment technology for the estimated quantity and quality of sewage sludge and for the currently prevailing conditions in Vietnam.

This report recommends that the Government actively discusses and promotes other ways than solid waste disposal. Vietnam’s Government should uphold and enforce the ‘polluter pays’ principle to improve the situation in a proportionate manner. There is a need for the Government to review the tariff policies for wastewater. Moreover, to exert pressure to enforce sewerage and solid waste tariffs for recovering the treatment costs is required. At least some costs will be recovered from the users and producers which can be reinvested to support a more sustainable services. In the future, Vietnam should invest in upgrading and expanding the treatment plants, enhancing to improve their capacity and use better treatment technologies.

The risk of sewage sludge has to be considered in all treatment processes and disposal paths, because “sewage sludge is the designated collector for all pollutants contained in the wastewater.”, as stated by Imhoff, K., [DICHTL, N. (2011), p. 21]. Generally, waste material can be re-used, taking into account the pre-condition that it is utilized in a environmental-friendly manner. Besides the management of sewage sludge, this cannot always be done. Consequently, two disposal paths can be considered as alternative methods for the utilization of sewage sludge in agriculture. On one thing, treated and well-stabilized sludge can be disposed of in landfill sites. Leachate, contamination, odour and methane emissions as well as non-sustainable management of land are huge problems of landfill sites and have been outlined in the paper. That is also why waste incineration (waste-to-energy disposal) will probably gain importance over the coming years. In Western Europe, waste incinerators have become an indis-
pensable part of waste management system for this matter which neither can be re-
duced nor re-used or recycled.

Related to the energy balance, in some cases sewage sludge treatment plants
can produce more energy than the handling of sewage sludge needs. Moreover, it pro-
vides valuable biosolids (secondary raw material) and energy. For all countries, the
treatment and re-use of sludge matters reduce greenhouse gas emissions by replacing
other resources. In addition, Vietnam is one of the worst affected countries of the world
in terms of climate change. Floods, the rising sea level, erosion and salination of water
resource in Vietnam are indisputable consequences of climate change. The initiatives
should not only take part against impacts of climate change, efforts towards the poten-
tial source – the ‘polluter’ should be stronger reinforced.

Concerning to the prospects of the future, sector needs are huge and the limited
capital and resources should be used for priority investments first. A strategy should be
established to consider most important priority of investments. The strategy is particu-
larly important in order to increase the efficiency of the funds deployed. Furthermore,
the decision making should ensure that sewage sludge treatment options are based on
the least cost and suitable technologies for Vietnam. National financing plans are re-
quired to face the investments to protect the environment.

In China and other ASEAN countries, annual investments for environmental
activities are accounting for 2 to 3 % of the country’s GDP. The sum of the environ-
mental fund in Vietnam is marginally 0.4 % of the GDP, [VIETNAM NEWS
(11/06/2011)].

As final a conclusion, the Vietnamese government should take into considera-
tion the extension of the national fund of environmental protection, to satisfy the current
and future demands for dealing with the increasing number of pressing environmental
issues.


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### Appendix A: Calculation of Sludge Amount

<table>
<thead>
<tr>
<th>given:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>population</td>
<td>87 million</td>
</tr>
<tr>
<td>distribution</td>
<td>27% urban, 73% rural</td>
</tr>
<tr>
<td>sludge produced</td>
<td>80 g/cap•d (activated sludge treatment, Europe)</td>
</tr>
<tr>
<td>water consumption</td>
<td>200 l/cap•d (Europe)</td>
</tr>
<tr>
<td>urban VN</td>
<td>150 l/cap•d (Vietnam)</td>
</tr>
<tr>
<td>rural VN</td>
<td>100 l/cap•d</td>
</tr>
<tr>
<td>sludge produced</td>
<td>60 g/cap•d (activated sludge treatment, Vietnam)</td>
</tr>
<tr>
<td>total sewer connection VN</td>
<td>? %</td>
</tr>
<tr>
<td>sewer connection</td>
<td>60% urban (Vietnam), 40% rural (Vietnam)</td>
</tr>
<tr>
<td>large City</td>
<td>75%</td>
</tr>
<tr>
<td>small City</td>
<td>45%</td>
</tr>
<tr>
<td>septic tanks (rural)</td>
<td>40% of households in Vietnam</td>
</tr>
<tr>
<td>septic tanks (urban)</td>
<td>77% of households in Vietnam</td>
</tr>
<tr>
<td>household</td>
<td>4-8 persons</td>
</tr>
<tr>
<td>number of households</td>
<td>21,75 million (4 person) Vietnam, 10,875 million (8 person) Vietnam</td>
</tr>
<tr>
<td>householdSeptic Tanks</td>
<td>16,747 million (4 person) Vietnam, 8,37375 million (8 person) Vietnam</td>
</tr>
<tr>
<td>Volume Septic Tanks</td>
<td>3 m³</td>
</tr>
<tr>
<td>Øρ sludge</td>
<td>1 g/cm³</td>
</tr>
</tbody>
</table>

#### Scenario I (X-% sewer connection)

<table>
<thead>
<tr>
<th>X-% sewer connection</th>
<th>Sludge rate</th>
<th>Scenario I (X-% sewer connection)</th>
<th>Scenario II (rural/urban) sewer multiplicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% sewer connection</td>
<td>87,000,000 cap*80g/cap•d/100,000 Mg/g</td>
<td>5220 MgTS/d VN or m³TS/d VN</td>
<td>278787,000,000<em>0.60g/cap•d</em>365</td>
</tr>
<tr>
<td>80% sewer connection</td>
<td>0.8·1905300 Mg/a</td>
<td>1524240 MgTS/a VN or m³TS/d VN</td>
<td>0.6·1905300 Mg/a</td>
</tr>
<tr>
<td>70% sewer connection</td>
<td>0.7·1905300 Mg/a</td>
<td>1333710 MgTS/a VN or m³TS/d VN</td>
<td>0.5·1905300 Mg/a</td>
</tr>
<tr>
<td>60% sewer connection</td>
<td>0.6·1905300 Mg/a</td>
<td>1141130 MgTS/a VN or m³TS/d VN</td>
<td>0.4·1905300 Mg/a</td>
</tr>
<tr>
<td>50% sewer connection</td>
<td>0.5·1905300 Mg/a</td>
<td>952650 MgTS/a VN or m³TS/d VN</td>
<td>0.3·1905300 Mg/a</td>
</tr>
<tr>
<td>40% sewer connection</td>
<td>0.4·1905300 Mg/a</td>
<td>762120 MgTS/a VN or m³TS/d VN</td>
<td>0.2·1905300 Mg/a</td>
</tr>
</tbody>
</table>

#### Scenario II (rural/urban)

<table>
<thead>
<tr>
<th>sewer multiplicator</th>
<th>Scenario II (rural/urban) sewer multiplicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.27·87,000,000<em>0.60g/cap•d</em>365</td>
<td>Sum 679557 MgTS/a VN</td>
</tr>
<tr>
<td>0.73·87,000,000<em>0.40g/cap•d</em>365</td>
<td>Sum 308534 MgTS/a VN or m³TS/d VN</td>
</tr>
</tbody>
</table>

#### Scenario III (Same TS in less WW)

<table>
<thead>
<tr>
<th>Sludge rate</th>
<th>Scenario I (X-% sewer connection)</th>
<th>Scenario II (rural/urban) sewer multiplicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sludge amounted 100%</td>
<td>87,000,000 cap*80g/cap•d/100,000 Mg/g</td>
<td>6960 MgTS/d VN or m³TS/d VN</td>
</tr>
<tr>
<td>Sludge amounted 80%</td>
<td>0.8·1905300 Mg/a</td>
<td>2032320 MgTS/a VN or m³TS/d VN</td>
</tr>
<tr>
<td>Sludge amounted 70%</td>
<td>0.7·1905300 Mg/a</td>
<td>1778280 MgTS/a VN or m³TS/d VN</td>
</tr>
<tr>
<td>Sludge amounted 60%</td>
<td>0.6·1905300 Mg/a</td>
<td>1524240 MgTS/a VN or m³TS/d VN</td>
</tr>
<tr>
<td>Sludge amounted 50%</td>
<td>0.5·1905300 Mg/a</td>
<td>1270200 MgTS/a VN or m³TS/d VN</td>
</tr>
<tr>
<td>Sludge amounted 40%</td>
<td>0.4·1905300 Mg/a</td>
<td>1016160 MgTS/a VN or m³TS/d VN</td>
</tr>
</tbody>
</table>

#### Scenario IV (rural/urban; same TS less WW)

<table>
<thead>
<tr>
<th>Sludge rate</th>
<th>Scenario I (X-% sewer connection)</th>
<th>Scenario II (rural/urban) sewer multiplicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sludge amounted 100%</td>
<td>87,000,000 cap*80g/cap•d/100,000 Mg/g</td>
<td>6960 MgTS/d VN or m³TS/d VN</td>
</tr>
<tr>
<td>Sludge amounted 80%</td>
<td>0.8·1905300 Mg/a</td>
<td>2032320 MgTS/a VN or m³TS/d VN</td>
</tr>
<tr>
<td>Sludge amounted 70%</td>
<td>0.7·1905300 Mg/a</td>
<td>1778280 MgTS/a VN or m³TS/d VN</td>
</tr>
<tr>
<td>Sludge amounted 60%</td>
<td>0.6·1905300 Mg/a</td>
<td>1524240 MgTS/a VN or m³TS/d VN</td>
</tr>
<tr>
<td>Sludge amounted 50%</td>
<td>0.5·1905300 Mg/a</td>
<td>1270200 MgTS/a VN or m³TS/d VN</td>
</tr>
<tr>
<td>Sludge amounted 40%</td>
<td>0.4·1905300 Mg/a</td>
<td>1016160 MgTS/a VN or m³TS/d VN</td>
</tr>
</tbody>
</table>
given:

- population: 87 million
- distribution: 27% urban, 73% rural
- sludge produced: 80 g/cap•d activated sludge treatment (Europe)
- water consumption: 200 l/cap•d (Europe), 150 l/cap•d (Vietnam)
- sewage produced: 80 g/cap•d activated sludge treatment (Vietnam)
- total sewer connection VN: ? %

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Sewer Connection</th>
<th>Sewage produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (100%)</td>
<td>87.000.000 cap*60g/cap•d</td>
<td>5220 MgTS/d VN or m³TS/d VN</td>
</tr>
<tr>
<td>80% connection</td>
<td>1905300 Mg/a</td>
<td>1524240 MgTS/a VN or m³TS/a VN</td>
</tr>
<tr>
<td>70% connection</td>
<td>1905300 Mg/a</td>
<td>1333710 MgTS/a VN or m³TS/a VN</td>
</tr>
<tr>
<td>60% connection</td>
<td>1905300 Mg/a</td>
<td>1143180 MgTS/a VN or m³TS/a VN</td>
</tr>
<tr>
<td>50% connection</td>
<td>1905300 Mg/a</td>
<td>952650 MgTS/a VN or m³TS/a VN</td>
</tr>
<tr>
<td>40% connection</td>
<td>1905300 Mg/a</td>
<td>762120 MgTS/a VN or m³TS/a VN</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario II (rural/urban)</th>
<th>Sewer multiplicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.27<em>87.000.000 cap</em>60g/cap•d</td>
<td>514431 MgTS/a VN or m³TS/a VN</td>
</tr>
<tr>
<td>0.73<em>87.000.000 cap</em>40g/cap•d</td>
<td>927246 MgTS/a VN or m³TS/a VN</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario III (Same TS in less WW)</th>
<th>Sewage produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sludge amounted 100%</td>
<td>87.000.000 cap*80g/cap•d</td>
</tr>
<tr>
<td>6960 Mg/d</td>
<td>365d/a</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario IV (rural/urban; same TS less WW)</th>
<th>Sewage produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.27<em>87.000.000 cap</em>80g/cap•d = 685908 MgTS/a VN or m³TS/a VN</td>
<td></td>
</tr>
<tr>
<td>0.73<em>87.000.000 cap</em>40g/cap•d = 1854492 MgTS/a VN or m³TS/a VN</td>
<td></td>
</tr>
</tbody>
</table>
### Senario V (septic tank) 78%

#### 4 Person

<table>
<thead>
<tr>
<th>Desluging Period</th>
<th>3 years</th>
<th>6 years</th>
<th>9 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desluging</td>
<td>16747500 m³/a VN</td>
<td>8373750 m³/a VN</td>
<td>8373750 m³/a VN</td>
</tr>
<tr>
<td>Mg/a VN</td>
<td>8373750 m³/a VN</td>
<td>8373750 m³/a VN</td>
<td>8373750 m³/a VN</td>
</tr>
</tbody>
</table>

#### 8 Person

<table>
<thead>
<tr>
<th>Desluging Period</th>
<th>3 years</th>
<th>6 years</th>
<th>9 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desluging</td>
<td>16747500 m³/a VN</td>
<td>8373750 m³/a VN</td>
<td>8373750 m³/a VN</td>
</tr>
<tr>
<td>Mg/a VN</td>
<td>8373750 m³/a VN</td>
<td>8373750 m³/a VN</td>
<td>8373750 m³/a VN</td>
</tr>
</tbody>
</table>

### Senario VI (Septic tank distribution rural/urban)

#### 4 Person

<table>
<thead>
<tr>
<th>Description</th>
<th>Rural 0.73</th>
<th>Urban 0.27</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desluging</td>
<td>21750000 ST * 3m³/ST*(1/3)*0.40</td>
<td>21750000 ST * 3m³/ST*(1/3)*0.78</td>
</tr>
<tr>
<td>Mg/a VN</td>
<td>3175000 m³/a VN</td>
<td>4580550 m³/a VN</td>
</tr>
<tr>
<td>Mg/a VN</td>
<td>3175000 m³/a VN</td>
<td>4580550 m³/a VN</td>
</tr>
<tr>
<td>Total</td>
<td>5465775 m³/a VN</td>
<td>10931550 m³/a VN</td>
</tr>
</tbody>
</table>

#### 8 Person

<table>
<thead>
<tr>
<th>Description</th>
<th>Rural 0.73</th>
<th>Urban 0.27</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desluging</td>
<td>21750000 ST * 3m³/ST*(1/3)*0.40</td>
<td>21750000 ST * 3m³/ST*(1/3)*0.78</td>
</tr>
<tr>
<td>Mg/a VN</td>
<td>3175000 m³/a VN</td>
<td>4580550 m³/a VN</td>
</tr>
<tr>
<td>Mg/a VN</td>
<td>3175000 m³/a VN</td>
<td>4580550 m³/a VN</td>
</tr>
<tr>
<td>Total</td>
<td>2732888 m³/a VN</td>
<td>5465775 m³/a VN</td>
</tr>
</tbody>
</table>

#### Desluging in 6 years period

<table>
<thead>
<tr>
<th>Description</th>
<th>Rural 0.73</th>
<th>Urban 0.27</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desluging</td>
<td>21750000 ST * 3m³/ST*(1/6)*0.40</td>
<td>21750000 ST * 3m³/ST*(1/6)*0.78</td>
</tr>
<tr>
<td>Mg/a VN</td>
<td>1526850 m³/a VN</td>
<td>2290275 m³/a VN</td>
</tr>
<tr>
<td>Mg/a VN</td>
<td>1526850 m³/a VN</td>
<td>2290275 m³/a VN</td>
</tr>
<tr>
<td>Total</td>
<td>2732888 m³/a VN</td>
<td>5465775 m³/a VN</td>
</tr>
</tbody>
</table>

#### Desluging in 9 years period

<table>
<thead>
<tr>
<th>Description</th>
<th>Rural 0.73</th>
<th>Urban 0.27</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desluging</td>
<td>21750000 ST * 3m³/ST*(1/9)*0.40</td>
<td>21750000 ST * 3m³/ST*(1/9)*0.78</td>
</tr>
<tr>
<td>Mg/a VN</td>
<td>1058500 m³/a VN</td>
<td>1526850 m³/a VN</td>
</tr>
<tr>
<td>Mg/a VN</td>
<td>1058500 m³/a VN</td>
<td>1526850 m³/a VN</td>
</tr>
<tr>
<td>Total</td>
<td>1821925 m³/a VN</td>
<td>3643850 m³/a VN</td>
</tr>
</tbody>
</table>

---

**B) GUIDELINE (DRAFT)**
Guideline (draft)

On the protection of the environment, and in particular the soil,
when sewage sludge is utilized in selected areas in agriculture

- This draft is supposed to serve as a basis for discussion between MoC and WWM Project –
(not to be circulated or distributed)

Whereas the objective of this guideline is to regulate the utilization of sewage sludge in agriculture in such a pathway as to prevent harmful effects on soil, vegetation, animals and human, while encouraging its correct utilization;

Whereas individual arrangements should be made to guarantee that human, animals, plants and the environment are fully safeguarded against the harmful effects arising from the uncontrolled utilization of sludge;

Whereas sewage sludge can have valuable agronomic properties and it is therefore justified to encourage its application in agriculture provided it is utilized properly; whereas the utilization of sewage sludge must not impair the quality of the soil and of agricultural products;

Whereas some heavy metals may exhibit toxic effects to plants and also to human through their presence in crops and whereas it is necessary to lay down mandatory limit values for these elements in the soil;

Whereas the utilization of sludge should be prohibited when the concentration of these metals in the soil exceeds these limit values;

Whereas, moreover, it is necessary to prevent these limit values from being exceeded as a result of the utilization of sewage sludge; whereas, to this end, it is necessary to limit the amount of heavy metals added to cultivated soil either by setting maximum quantities for the amounts of sewage sludge utilized per annum and ensuring that the limit values for the concentration of heavy metals in the sewage sludge utilized are not exceeded or by seeking to ensure that limit values for the quantities of heavy metals that can be added to the soil on the basis of a 10-year average are not exceeded;

Whereas sludge must be treated before being utilized in agriculture, whereas it may nevertheless authorized on certain conditions, the utilization of untreated sludge, without risk to human or animal health, if it is injected or worked into the soil;
Whereas a certain period must elapse between utilizing the sewage sludge and putting stock out to pasture or harvesting fodder crops or certain crops which are normally in direct contact with the soil and normally consumed raw; whereas the utilization of sludge on fruit and vegetable crops during the growing season, except for fruit-tree crops, must be prohibited;

Whereas sewage sludge should be utilized under condition which ensured that the soil and the surface and ground water are protected;

Whereas to this end it is necessary to monitor the quality of sewage sludge and of the soils on which they are utilized and hence to make analyses and to communicate certain results to the responsible ministry and authority (MoNRE);

Whereas a certain amount of essential information should be kept to ensure better awareness of the utilization of sewage sludge in agriculture and whereas such information should be forwarded in the form of periodic reports to the responsible ministry and authority (MoNRE);

Whereas sludge from small sewage-treatment plants which treat primarily domestic wastewater represents little risk to human, animal and plant health and to the environment and should therefore be exempt from some of the obligations laid down relating to information and analysis;

Whereas the Socialistic Republic of Vietnam should be able to draw up more stringent provisions than those laid down in this guideline;

Whereas technical and scientific progress may make necessary the rapid adaptation of certain requirements.

Article 1 - Objective
The objective of this guideline is to regulate the utilization of sewage sludge in agriculture in such a pathway as to prevent harmful effects on soil, vegetation, animals and human; thereby encouraging its correct utilization.

Article 2 - Scope
This guideline should be paid to,

(a) operators of wastewater treatment plants (including sewer systems) accumulating sewage sludge, which is treated and stored, operator who discharge or intend or are obligated to discharge sewage sludge.

(b) direct utilizers of sewage sludge dealing and handling with the sewage sludge, utilizer who discharge or intend or are obligated to discharge sewage sludge.

Article 3 - Definitions
For the purposes of this guideline:

(a) 'sludge' means:
(i) residual sludge from sewage plants treating domestic or urban waste waters and from other sewage plants treating waste waters of a composition similar to domestic and urban waste waters;
(ii) residual sludge from septic tanks and other similar installations for the treatment of sewage;
(iii) residual sludge from sewage plants other than those referred to in (i) and (ii);
(iv) sludge from sewer systems
(v) dredged sludge of wastewater channels in urban areas

(b) 'treated sludge' means:
sludge which has undergone biological, chemical or heat treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use;

(c) 'agriculture' means:
the growing of all types of commercial food crops, including for stock-rearing purposes;

(d) 'utilize' means:
the spreading of sludge on the soil or any other application of sludge on and in the soil.

Article - 4 Application

The sludge referred to in Article 3 (a) (i) to Article 3 (a) (v) may only be utilized in agriculture in accordance with this guideline.

Article 5 - Condition for the utilization

(1) The utilization of sewage sludge must not impair the general good. The sewage sludge should be utilized in selected areas in agriculture in such a pathway as to prevent harmful effects on soil, vegetation, animals and human.

(2) The sludge which is supposed to be utilized in selected areas in agriculture, must be first analyzed according to Annexes II B and II C before utilized.

(3) Soil analyses have to be repeated in 10 year periods. In adjustment with the responsible authority (MoNRE), it has to regulate the periods in which the principle utilizer of sewage sludge have to analyze and report their results. The responsible authority is able to draw up more stringent provisions and can prohibit the utilization.

(4) Sewage sludge can be utilized on soils, which have been observed and analyzed on pH value, content of nutrients suitable for plants as phosphorous, potassium and mag-
nesium. Operators of wastewater treatment plants have to cover the cost for this analysis.

(5) Sewage sludge, which has been observed and analyzed on
- concentration of lead, cadmium, chrome, copper, nickel, mercury;
- absorbable halogen hydrocarbons (AOX);
- concentration of total nitrogen, ammonium, phosphorous, potassium, total solid content, organic solid content, and pH value;

by certificated laboratories, can be utilized in agriculture

(6) Operator of wastewater treatment plants have to sample and analyze as formulated at clause 2, 3 and 5 in accordance to Annexes II A, II B and II C.

(7) The sludge from small sewage-treatment plants in agricultural companies can be utilized on company-owned areas and are exempted of clause 2 to 6. Sewage sludge must first ensure to be analyzed according to clause 5.

(8) Sludge from small sewage-treatment plants with the capacity below 300 kg BOD$_5$ per day, corresponding to 5,000 population equivalents, which are designed primarily for the treatment of domestic wastewater are exempted of clause 2 to 6. The sludge which is supposed to be utilized in selected areas in agriculture and must first ensure be analyzed according to Annexes II B and II C.

Article 6 - Utilization limits and rules

(1) The utilization of raw sludge or sludge from other wastewater treatment plants as referred to in Article 3 (a) (i) to 3 (a) (v) are prohibited.

(2) Values for concentrations of heavy metals in soil to which sludge is applied as well as concentrations of heavy metals in sludge and the maximum annual quantities of such heavy metals which may be introduced into soil intended for agriculture are given in Annexes I A, I B and I C.

(3) The authorities (MoNRE) shall prohibit the utilization of sludge in Article 3 (a) and (b) or the supply of sludge for utilization on:

(a) grassland or forage crops if the grassland is to be grazed or the forage crops to be harvested before a certain period has elapsed. This period, which shall be set by the responsibilities (MoNRE) taking particularly into account the geographical and climatic situation, shall under no circumstances be less than three weeks;

(b) soil in which fruit (including rice crops) and vegetable crops are growing, with the exception of fruit trees;
APPENDICES

(c) ground intended for the cultivation of fruit (including rice crops) and vegetable crops which are normally in direct contact with the soil and normally eaten raw, for a period of 10 months preceding the harvest of the crops and during the harvest itself.

(4) The following rules shall be observed when utilizing sludge:

- the sludge shall be utilized in such a pathway that account is taken of the nutrient needs of the plants and that the quality of the soil and of the surface and ground water is not impaired,

- where sludge is utilized on soils of which the pH is below 6, it shall take into account the increased mobility and availability to the crop of heavy metals and shall, if necessary, reduce the limit values they have laid down in accordance with Annex I A.

**Article 7 - Exceptional cases**

Where conditions so demand, responsibilities may give exceptional cases for detailed bounded areas to utilize sewage sludge from Article 3 (a) and (b).

**Article 8 - Amount of sludge utilized**

The responsibility (MoNRE) shall restrict the amount of sludge according to Article 3 (a) and (b) which shall be utilized on selected areas in agriculture (in tons per year and hectare).

**Article 9 - Obligation to produce records**

Utilizers outlined in Article 2 (a) and (b) shall ensure that up-to-date records are kept, which register:

(a) the quantities of sludge produced and the quantities supplied for use in agriculture;

(b) the composition and properties of the sludge in relation to the parameters referred to in Annex II A;

(c) the type of treatment carried out, as defined in Article 3 (b);

(d) the names and addresses of the recipients of the sludge and the place where the sludge is to be utilized.

(2) The records shall be available to the competent authorities and shall provide a basis for the consolidated report.

(3) Information on the methods of treatment and the results of the analyses shall be published upon request to the competent authorities.

**Article 10 - Application plan**

The responsible agricultural departments has to develop and formulate the per annum application plan and the process of utilization related to the calendar year.
Article 11 - Research

Adaption to technical and scientific progresses is required. Relevant ministries shall jointly develop research plans and carry out detailed researches on the utilization of sewage sludge in selected areas in agriculture in Vietnam.

Article 12 - Adjustment of this guideline

Where conditions so demand, authorities may take more stringent measures than those provided in this guideline.

This guideline has to be peer-reviewed by experts, professionals and specialists from the various departments.

Limits for heavy metals in soil and sludge are given in approximate ranges and have to be regulated by responsibilities as the condition demand.

Penalties for violation of this act have to be worked out and formulated in the framework of this guideline.
DECLARATION

The work presented in this diploma thesis is to the best of my knowledge and belief, original, except as acknowledged in the text. This material has not been submitted, either in the whole or in part, for a degree in this or in any other university.

Ralf Karius
Dresden, July 2011

EIDESSTATTLICHE ERKLÄRUNG


Ralf Karius
Dresden, July 2011