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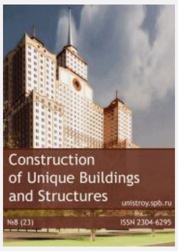

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Drinking water contamination caused by uncontrolled landfills

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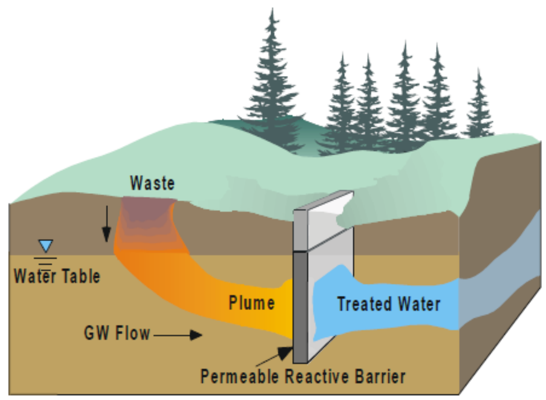
ABSTRACT



Filtration system of a cut-off wall (EPA, 1998 [15])

The following article deals with the worldwide problem of drinking water contamination caused by uncontrolled waste landfills. The population of the world is increasing and more waste is produced which needs to be disposed. Uncontrolled waste landfills are not managed and badly engineered, triggering the danger of groundwater pollution. By taking this groundwater as the first source for drinking water it could affect human health. The aim of this research is to present solutions to prevent groundwater pollution in a sustainable way. This article presents three different approaches to tackle this problem, compares their strengths and flaws and finally points out the best solutions measured by cost, effort and sustainability.

Contents

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1. Introduction

This paper will report on the problem of drinking water contamination caused by uncontrolled waste landfills.

For decades, the world population is growing; especially the population of developing countries such as India or China is increasing enormously. But more people in the world mean more waste is produced and more space for this waste is needed. Since managing waste is costly and often knowledge about correctly storing it is lacking, waste is dumped anywhere without managing and controlling this site. These so called *uncontrolled waste landfills* (figure 1) are a great danger for the groundwater and implicate a risk for human health.

Figure 1. Uncontrolled waste landfill, Brazil (DW, 2002 [1])

As can be seen in figure 2, the waste is dumped without any protection between waste and ground. Because of rainwater the risk of infiltration occurs and a liquid mixture of particles, which is known as **landfill leachate**, reaches the groundwater and affects the quality of drinking water. Therefore the **objective** of this research is to find and list sustainable solutions for the impact on the drinking water quality caused by groundwater pollution of uncontrolled municipality waste landfills. The results will be presented by comparing three solutions by cost, effort and sustainability.

2. Literature review

Groundwater pollution is a problem which affects the whole planet and threatens especially the management of drinking water supply. Basically, groundwater pollution appears when hazardous substances come into contact and suspend in the water that has seeped into the ground. [2]

Groundwater is not visible because it is – as the name implies – almost always hidden underground and furthermore the most important source for drinking water worldwide. Around 30% of the world's freshwater is groundwater (figure 2) and 97% of it is potentially available for human use. [3]

By having the danger of drinking water contamination the European Drinking Water Directive (DWD) is rightly required to make sure that the drinking water is free from bacteria and viruses and to check the limit values of all the chemicals inside [4].

In 1999 a directive for a certain standard for controlling and managing landfill sites has been introduced by the European Commission. The deadline for implementation of the legislation in the Member States was July 2001, with the aim of preventing negative effects on the environment as fast as possible by introducing stringent technical requirements for waste and landfills [5].

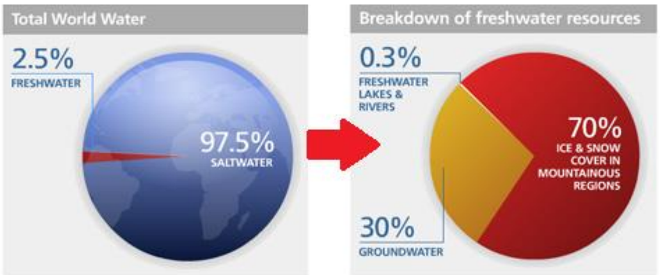

Figure 2. World Water Resource (UNWATER, 2012 [3])

In 2012 a study about the groundwater contamination was released by Dr. Mohamed Ismail who introduced different techniques for landfills such as a Cut-Off wall system or chemical treatment of the water. [6] But in general there is a lack of measuring possible solutions by comparing them.

3. Problem definition

What is leachate?

Basically leachate is a liquid that moves through a landfill. It has its origin mostly from rainwater and carries all kinds of bacteria and particles of the waste. Common municipality waste landfill leachate has high concentrations of nitrogen, iron, organic carbon, manganese, chloride, phenols and heavy metals. As leachate liquid leaks from a landfill site, it has a strong acidic smell and is often black or yellow (figure 3). [7]

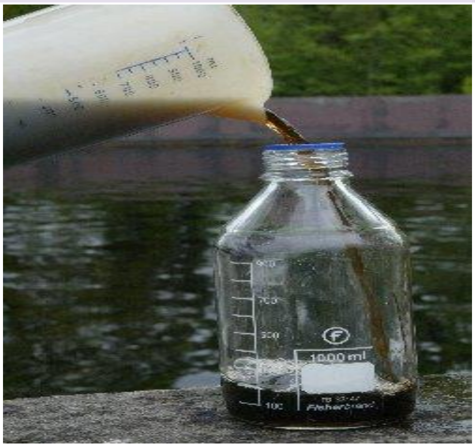

Figure 3. Test sample of landfill leachate (IAPG, 2006 [8])

After running through waste and solid, the toxic mixture reaches the groundwater aquifer. If this happens, the groundwater is called polluted and the drinking water contains all kinds of harmful particles. Particularly **heavy metals** are a great hazard for drinking water. Heavy metals have a lot of origins in the waste. Lead for example is occurring in building materials, pigments for glazing ceramics or pipes for transporting water. Chrome is used for all kinds of layer of corrosion, is found in leather, glass and parts of a car. Copper is mainly used in industry for electronically productions and technologies. It is known that drinking water, which contains more than the limit values for heavy metal substances, can lead to several diseases and toxicities.

4. Description of the research

4.1 Methodology

The methodology of this research is divided into three parts: Data Collection, Data Analyses and Discussion.

The first part explains the way how to collect the information, which means what kind of sources will be used. The sources, which are secondary literature, consist mainly of books, internet sources or articles. To learn more about the water directives in Europe the “European water regulations” are taken into consideration. Furthermore the kinds of landfills will be studied to receive information about the build-up of domestic waste landfills, the different types of domestic waste which are stored and the different techniques to eliminate toxic substances from groundwater. Articles about hazards of groundwater, landfills and example cases to learn from the past to suggest improvements were red as well.

The data analysis will interpret the collected data and analyse the different techniques of storing waste and of reducing pollution of groundwater. Directives and regulations for drinking water quality will help to know the limiting values for substances in drinking water. With example cases it is possible to learn from the past and to improve techniques. With the analyzed data environmental and technical solutions will be described with regard to the main objective, to eliminate leachate and to minimize the polluted groundwater. To suggest the most promising result a discussion of all the solutions will be made by comparing them by cost, effort and sustainability.

4.2 Data Collection and Analyses

Solution 1: Liner System – with leachate treatment

Liner systems for landfills are planned and constructed to create an interface among the waste and the environment and to lead the leachate to collection and treatment facilities. This is used to avoid the uncontrolled escape of leachate into the soil and groundwater. [8] The structure of liner systems differs from type to type. There are three kinds of systems, namely single-liner, double-liner and composite-liner system. They share the fact that all systems have a geomembrane as a basis (figure 4). For municipality waste, a composite liner system is mostly used [9].

Figure 4: Geomembran Liner (Wordpress, 2004 [10])

It consists of a combination of a geomembrane and a clay liner and is therefore more effective in leachate mitigation. Geomembranes are constructed from high-density polyethylene (HDPE) which is strong, resistant to chemicals and waterproof to protect the soil and the groundwater in case the leachate system is not working. The geotextile is used to protect the leachate collection system from small soil and the geomembrane from cuts. The leachate collection system consists of pipes (figure 5) to collect the leachate and lead it to tanks for storage or treatment. In order to run a sustainable liner system, the collected leachate needs to be treated. With regard to removing heavy metals, a special leachate treatment system is used – the chemical precipitation of metals [11].

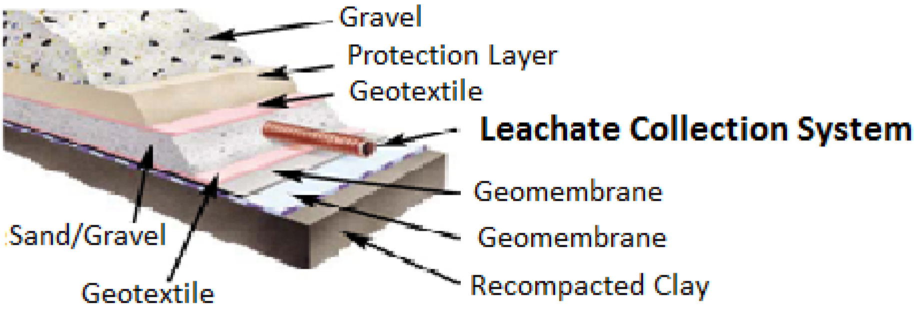

Figure 5: Composite Liner with leachate collection system (Rawell, n.d. [11])

Chemical precipitation is the most common way to deal with dissolved heavy metals in leachate. During this chemical process, solvable metal ions are transformed into insolvable salts. These salts can be removed by filtration or sedimentation and become a clarified and highly-concentrated metal sludge. The U.S. Environmental Protection Agency (EPA) tested all kinds of leachate treatment systems and created treatability data for every pollutants. This data shows that the chemical precipitation is working with an removal efficiency of 90% for copper, 95% for lead and even 99% for chrome by an influent concentration range of 10-100 mg/Liter. [12]

The costs for designing and constructing this liner system with leachate treatment are measured as follows:

- Composite liner system:
  4,416,622€/ha (5.988.056$/ha) [13]

- Chemical precipitation of metals:
  84,867€/L (112,746$/L) [14]

TOTAL: 4,501,500 € (6,100,802$)

Solution 2: Permeable cut-off walls

Permeable cut-off walls are used to keep contaminated groundwater away from the drinking water intake. These underground barriers are build-up of a vertically excavated ditch that is filled up with slurry consisting of a soil, bentonite and water mixture. The slurry hydraulically reinforces the ditch to avoid a collapse and creates a filter to reduce ground water flow. After that a soil-bentonite refill material is filled in the ditch and displaces the slurry to form the cut-off wall. Whenever contaminated groundwater, or plume, is seeping out of a landfill site, it will pass the barrier and will be treated with filtration (figure 6) [14].

The size and amount of these walls is depends on the landfill site and the groundwater flow. Sometimes a single wall is enough to avoid contamination but in many cases the site is completely surrounded by them. They are generally placed at depths up to 30 meters and are about 0.6 to 1.2 meters thick. The most operative use of the cut-off wall for site decontamination or pollution control is to key the cut-off wall 0.6 to 0.9 meters into a low permeability layer such as clay or bedrock (Figure 7). This basement guarantees an effective foundation with a very low leakage potential (2012). Furthermore, groundwater controls are implemented to manage and control the values of the groundwater. The simplest and less expensive solution is a so called observation well. [15] Inside the cut-off wall is also a chemical precipitation system which eliminates heavy metals (already described in solution 1) [17].

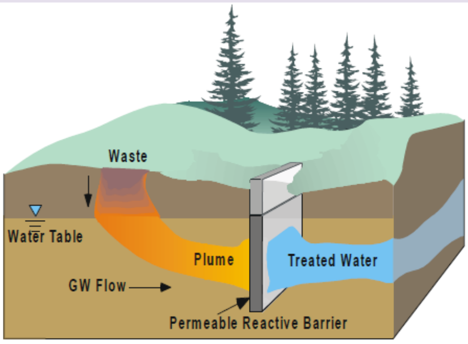

Figure 6: Filtration system of a cut-off wall (EPA, 1998 [15])

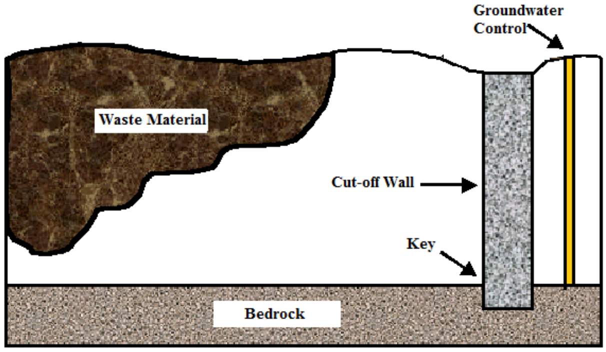

Figure 7: Cut-off wall with a foundation and groundwater control (Frtr, 2012 [14])

The costs for designing and constructing cut-off wall system with leachate treatment are measured as follows:

– The average price for a cut-off wall is:
4,830,000€/ha (6,450,000$/ha) [14]

– Chemical precipitation of metals:
84,867€/L (112,746$/L) [14]

TOTAL: 4,914,867€ (6,562,747$).

Solution 3: Landfill Mining

Landfill mining describes the process of reusing solid waste which has previously been landfilled through excavating and treating it. The main reasons for landfill mining are creating new space for future landfills, addressing groundwater pollution, recovering recyclable materials and reducing closure costs [18].

There are three general steps which describe landfill mining: dig up, sieve and sort. At the beginning, an excavator (Figure 8) starts to dig up waste out of the landfill. After that the excavated waste is processed to separate unwieldy materials, sorting hazardous material and materials to be used as fuel or recycling. One way to separate the recyclable materials, especially heavy metals, is to use a magnet. Recyclable materials are plastics, glass and ceramic, metals and stone or aluminum. The non-recyclable excavated waste is treated with a so called waste shredder to small particles. It is sorted and filtered again until only soil is left [18].

Figure 8: Waste excavation (FDEP, 2009 [17])

By reusing all of the recyclable materials, especially heavy metals can be kept away from the waste and therefore from the groundwater. Furthermore, the metals can be sold as secondary resources, which is for copper very important these days.

The opportunity of producing energy from waste is a big advantage of landfill mining. Because the waste is not stored but reused, waste power plants are becoming more interesting specifically for uncontrolled and old landfills. Besides waste burning which is very efficient, another system is currently being developed. This system, called gas plasma technology, is working with non-recyclable materials which were dried and shredded by turning it into Refused Derived Fuel (RDF). The RDF is put into a fluid bed gasifier in which it is transformed into synthetic gas. This gas is passed into a separate plasma converter and a pure, hydrogen-rich synthetic gas is produced (figure 9) [19].

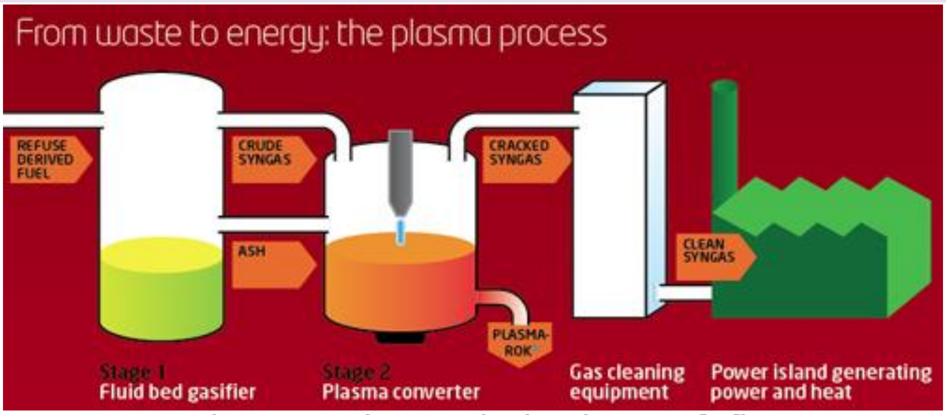

Figure 9: Gasplasma Technology (CM, 2012 [20])

The costs for landfill mining depend on the size of the landfill and the technology. The average price of excavating and mining the waste is 4,91 €/m³ (6,53 $/m³) (FDEP, 2009). By an average waste size of 400,000 m³ the excavating and mining cost would be 1,964,000 €/m³ (2,611,924$/m³) (FDEP, 2009). All together the costs of a landfill mining project are estimated **about 60 million Euro** with regard to the Enviropark in Hirwaun, Wales. [21].

4.3 Discussion

As indicated above, the result which is the best solution will be measured by cost, effort and sustainability and is presented in table 1.

Table 1: Comparison of the three solutions

	1. Liner-System	**2. Cut-Off Wall**	**3. Landfill Mining**
Cost	4,501,500€	4,914,867€	60 million €
Effort	– Special companies – Excavating waste – Cleaning soil – Maintenance	– Special companies – Complicated machinery – A lot of time – Maintenance	– No complex machinery – Daily routine
Sustainability	– Treated water can be reused	– Treated water can be reused – Low harming of the environment	– Recycling materials – Producing energy – Profitable after ten years

It can be seen that solution 1 (Liner-System) is with about 4.5 million Euro the most inexpensive solution, solution 2 (Cut-Off Wall) with about 5.0 million Euro and solution 3 (Landfill Mining) with 60 million Euro are more expensive. Looking at the effort of solution 1 and 2 are more complicated and costly in terms of time compared to solution 3 which has a daily routine.

Even though landfill mining is with its starting costs very expensive it is profitable after ten years. Furthermore the effort and sustainability give a reason to appoint landfill mining to the best solution for preventing the contamination of drinking water caused by uncontrolled landfills.

4.4 Recommendation

This research showed that the best solution to prevent drinking water contamination caused by uncontrolled landfills is landfill mining. To implement this solution a special focus should be on the costs. Landfill mining has with its whole project costs a disadvantage. Therefore a further research should keep an eye on cooperations or sponsoring to reduce the costs in the beginning. Moreover, a further research can be based on other existing techniques to produce energy instead of gas plasma to point out strength and weaknesses.

5. Conclusion

This report has examined the problem of drinking water contamination caused by uncontrolled waste landfills. It suggested three solutions for this problem and analyzed them by the measurements of cost, effort and sustainability. Because the waste is not dumped correctly and the sites are badly engineered, rainwater can seep into the ground contaminating the groundwater.

By facing this problem three solutions were suggested which are: Liner System, Permeable Cut-Off Wall and Landfill Mining. The analyzed solutions for improving uncontrolled landfills can all solve the problem of contaminated drinking water. The research showed that compared by cost, effort and sustainability, landfill mining is the most promising solution. Even though the starting costs are with 60 million Euros very high, money is earned by recycling materials and producing green energy which will be profitable after only ten years. The effort is low because just a view machines are needed and the maintenance is smaller compared to the other solutions. Furthermore, it is the most sustainable solution by reusing almost all of the waste and producing green energy.

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Загрязнение питьевой воды как следствие отсутствия контроля над полигонами для захоронения отходов

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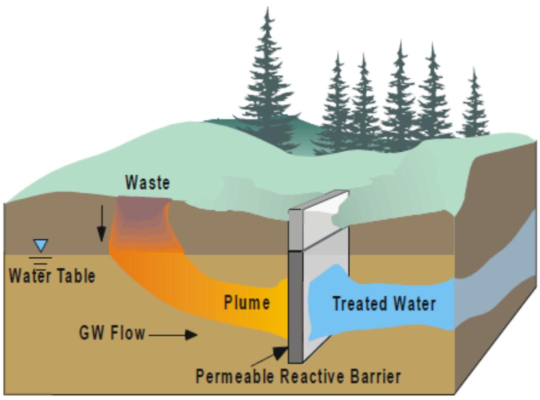
Научная статья	Подана в редакцию 2 февраля 2014 Принята 27 июля 2014	питьевая вода, загрязнение, грунтовые воды, полигоны для захоронения отходов, неконтролируемое загрязнение, сточные воды, тяжелые металлы, устойчивая среда.

АННОТАЦИЯ



Filtration system of a cut-off wall (EPA, 1998 [15])

В статье рассмотрена мировая проблема загрязнения питьевых вод, возникшая вследствие неконтролируемого загрязнения и увеличения полигонов для захоронения отходов. Популяция мирового населения возрастает и появляется все больше отходов, которые необходимо утилизировать. Многие полигоны для захоронения отходов не оснащены должным образом с инженерной точки зрения, не учитывается степень загрязнения грунтовых вод. А загрязненные воды пагубно влияют на здоровье человека. Результатом исследования стало представление трех подходов по предотвращению грунтовых загрязнений и поддержанию дальнейшего направления устойчивого развития.

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