Environmental Technology
Changing Challenges in a Changing World

Abstracts of the farewell symposium of

Prof.dr.ir. Wim H. Rulkens

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Wageningen, The Netherlands

Foreword

Environmental Technology started to develop in the seventies of the last century in response to societal alerts on polluted water systems. Similar alerts in the eighties initiated the development of soil and sediment remediation technologies.
In those days Environmental Technology focused on the removal and (bio)degradation of pollutants in the different environmental compartments. Today the sustainable (re)use of water and soil as such, after a specific treatment, has gained an increased attention.

Since 1989 prof. dr. ir. Wim Rulkens is the Chair of the **Sub-department of Environmental Technology at Wageningen University**. In this position he was highly involved in the changing challenges in the discipline of Environmental Technology world-wide. On the occasion of his retirement per 1-12-07 we organized a Farewell symposium entitled:

Environmental Technology
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Environmental Technology still is a young discipline, and faces a wide variety of new challenges. The Sub-department of Environmental Technology is working on several of these challenges. In this book of abstracts you will find presentations of these challenges in the field of water treatment, soil remediation and production of sustainable energy by Jules van Lier, Huub Rijnaarts and Cees Buisman, respectively.

Many Environmental Technologies are exported and transferred to Asia and Eastern Europe. Aspects determining the success of their introduction in these societies are addressed, based upon their own experiences, by prof. Nguyen Trung Viet (Vietnam), dr. Jian Chen (China) and prof. Greg Malina (Poland).

Besides new technologies and technology transfer the most important products of the Sub-department of Environmental Technology are graduated students. The success of Environmental Technology is strongly dependent upon the professionals that advocate and apply these technologies. Many of these graduated students are active at consultancy firms. The vision of consultancy firms upon the multitasking qualities of young environmental technology engineers is outlined by ir. Bram de Borst.

Environmental Technology is linked to a wide variety of scientific disciplines. Scientific breakthroughs may lead to complete new Environmental Technologies, like the development of microbial fuel cells. Some already dare to talk about the third generation wastewater treatment plants in which production of electrical power by microbial fuel cells will be combined with wastewater treatment. Prof. Willy Verstraete (Belgium) shares here his visions with us on possible future developments in Environmental Technology.

The organizing committee:
Tim Grotenhuis
Harry Bruning
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Water and the sustainable use of an “abundant” resource

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Abstract
The water planet “earth” is far from a lack of water. However, high-quality process water and drinking water is becoming a scarce commodity at various locations of the world. In fact, fresh water availability limits the (socio-)economic development of many places, particularly in developing countries. Environmental technologies, designed for treating and reclaiming water for subsequent usage in a productive chain are becoming crucial in modern water strategies. In principle, all water can be turned into drinking water but financial constraints limit the applicability of proper (waste)water treatment technologies. The current challenge is to develop cost-effective treatment technologies, oriented to the recovery of resources from waste streams, while reclaiming our most precious “abundant” resource for multiple usage. A multidisciplinary approach to embed these technologies in the existing socio-economic context is a prerequisite for success.

Introduction

The estimated net quantity of water which is transported from our marine reservoirs to the land mass is about 40.000 km^3 per year, representing the estimated land-based precipitation minus the evapo(-transpi)ration, which means an average current per capita availability of 6000 $m^3.person^{-1}.year^{-1}$. Obviously, there is huge inequity in the geographic distribution of the available water, resulting in countries facing severe water shortages. Water *stressed* countries have annual renewable water resources between 1000-1700 $m^3.person^{-1}$. Surprisingly, the European countries Belgium, Poland and UK also belong to this category. Countries suffering from water *scarcity* have less than 1000 $m^3.person^{-1}year^{-1}$ available (http://www.infoforhealth.org). The projected 2025 per capita water availability forecast shows 29 water scarce countries with values as low as 50-150 $m^3.person^{-1}.year^{-1}$ for various countries in The Gulf, North Africa and Middle East. In addition, 19 countries are projected to become water stressed. For comparison, the Netherlands’ population consumes about 50 $m^3.person^{-1}.year^{-1}$ for domestic purposes, while for USA this is about 4-fold higher. The latter values illustrate the severe water problems for the mentioned arid regions, not only for industrial and agricultural activities but even for domestic uses. Combining the water scarcity with the projected population growth of 1-3%, while accepting that the population increase will occur in the large cities, makes you realize that the generally applied urban water chain needs to undergo drastic changes in order to comply with the needs of the people. Of the 21 megacities bigger than 10 million people, 14 are located in developing countries, 2 in China and 5 in the industrialized countries…

A matter of immediate concern is the fact that treatment of industrial and urban wastewater treatment is still hardly applied in developing countries: Asia ≈ 35%, Latin America ≈ 14%, Africa… (WHO/Unicef, 2000). As such, the scarcely available water resources are heavily threatened, affecting the basic water supply for the community.

Current challenges: industries

Since the net water flux by evaporation and precipitation will not change in future, albeit regional and seasonal differences may increase, drastic changes in water management are required to prevent acute water shortages. The multiple use of water, i.e. the application of appropriate treatment and reuse of reclaimed water is more and more explored to cover the urban water needs (IWA Conf. Wastewater Reclamation and Reuse, Antwerp, Belgium, October 9-12, 2007). In addition to the ‘increase’ in the available water resources, the ‘water reuse concept’ also prevents pollution of surface and groundwater by non- or partially treated wastewater.

It must be noted that re-arranging the conventionally applied water cycles in urban areas and industries/industrial estates, offers many more advantages than solely ‘increasing’ the water availability. The main drivers in Dutch industries to optimize their water circuits are related to:

- Optimized usage of raw materials (less losses).
- Optimized energy efficiency. Considering the fact that heating surface water and groundwater to production temperatures costs 4.2 MJ.$^{o}C^{-1}$.m^{-3}, signifies an immediate energy benefit if treated process water is reused in the production process.
- Reduced costs related to water intake taxes and costs for drinking water/ industrial water.
- Reduced costs for waste water conveyance and treatment

Water shortage hardly plays a role in the Netherlands were only 10% of the renewable water sources are used for industrial, agricultural and domestic purposes. The water treatment and reuse concepts developed here offer interesting perspectives for water-stressed or water-scarce countries to implement the cleaner production principle with an optimized water circuit as a result.

Since water is the prime medium transporting raw materials to, and waste products from, the place of production, wastewater will always be generated. Efficient process water recycling leads to more concentrated waste steams which then can be cost-effectively treated by modern anaerobic high-rate technologies. Several anaerobic reactor systems are currently operated at loading rates beyond 40 kg COD.m^{-3}.day^{-1}, a major improvement since the development of these systems (Fig. 1).

Compared to the conventional approach there are many striking advantages for implementing anaerobic treatment (van Lier, 2007) of which the reduced excess sludge production by 90% and the reduced space requirement also by 90% are of main interest for applications in densely populated areas like The Netherlands. It should be noted that sludge landfilling is no option any more for excess biosolids, while prices for incineration reach € 500/ton wet sludge or even higher. Interestingly, the compactness of the tower-like systems facilitates water recycling in factories (towards closed loops) as they can be constructed adjacent or even inside the industry. At present, there is a renewed interest in the energy efficiency of anaerobic treatment avoiding the use of fossil fuels for treatment, saving about 0.5-1 kWh.kg^{-1} COD removed. Moreover, anaerobic high-rate systems produce about 13.5 MJ CH_4 energy.kg^{-1} COD removed, giving 1.5 kWh-electric (assuming 40% electric conversion efficiency). COD conversion rates of 30-35 kg COD.m^{-3}.day^{-1} then result in an energy output of 2 kW.m^{-3} reactor volume!

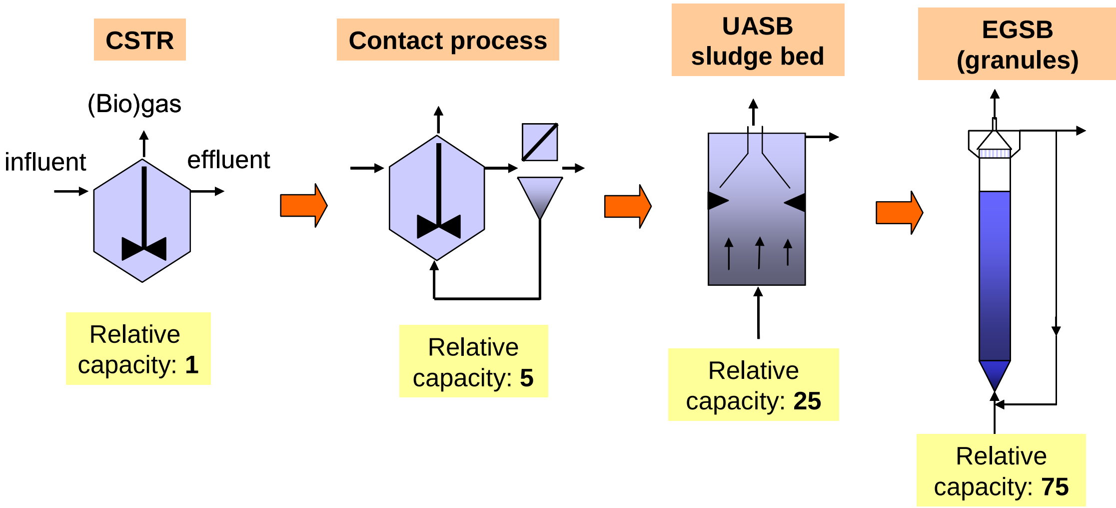

Figure 1. Relative loading capacity of different anaerobic wastewater treatment systems. Maximum applicable loading rates under full scale conditions reach about 45 kg COD.m^{-3}day^{-1} using EGSB type systems.

The renewed interest in the energy aspects of anaerobic treatment directly results from the ever rising energy prices and the overall concern on global warming. For example, by anaerobically treating 25 tons COD.day^{-1} of agro-industrial waste(water), a volume of 7000 m^3 methane.day^{-1} (assuming 80% CH_4 recovery) can be produced, with an energy equivalent of about 250 GJ.day^{-1}. Working with a modern combined heat power (CHP) gas engine, reaching 40% efficiency, a useful 1.2 MW electric power output can be achieved. The overall energy recovery could even be higher (reaching up to 60%) if all the excess heat can be used on the industry premises or direct vicinity. Assuming that full aerobic treatment would require 0.5-1 kWh.kg^{-1} COD removed, or 0.5-1 MW installed electric power in the above case, the total energy benefit of using anaerobic treatment over an activated sludge process is 1.7-2.2 MW. At an energy price of 0.1 €.kWh^{-1} this maximally equals about 5000 €.day^{-1}.

Apart from the energy itself, current drivers include the carbon credits that can be obtained by generating renewable energy using anaerobic treatment. For an average coal-driven power plant, the generation of 1 MW-electric emits about 20 ton CO_2.day^{-1}. At a foreseen stabilised price of € 20.ton^{-1} CO_2, the above exampled industry could earn € 150.000.year^{-1} on carbon credits, while no fossil fuels are used for treating the wastewater. Although this amount is negligible in industrialised countries, it could provide a real incentive in developing countries to start treating the wastewater using high-rate anaerobic treatment, and thereby protecting the local environment. In this way, the carbon credit policy can be regarded as a potential Western subsidy for implementing cost-effective wastewater treatment systems in the less prosperous countries.

Novel developments in anaerobic technologies are oriented to broadening the field of applications anticipating on the more frequently occurring extreme conditions like high temperatures, high salinities, accumulating refractory and/or toxic compounds, etc. It is still questionable whether sludge bed systems are still feasible under such conditions, as formation of stable and dense granular aggregates are affected by extreme environmental conditions. Under such conditions, anaerobic membrane bioreactors may offer an attractive alternative as recently shown by Jeison (2007). Although, achieved fluxes, based on achievable critical fluxes, did not exceed ≈ 20 l.m^{-2}.h^{-1}, current expectations are to double or triple this value.

Indeed, investment costs and (auto-generated) energy input will increase. However, the compactness, low sludge production and non-usage of fossil fuels will remain as main driver for implementation.

Obviously, anaerobically treated wastewater cannot be considered reclaimed water for production processes. In addition, to this pre-treatment subsequent steps are required to reach specific levels for reuse. Current developments on membrane-based separation processes, enhanced oxidation, physico-chemical disinfection techniques, etc., may, in conjunction with a cost-effective removal of bulk pollutants, result in complete regeneration of process water reducing the consumptive water and energy use to a minimum.

Current challenges: the urban water chain

Optimising water use in industries is relatively easy since, in the end, economics will determine decisions. The industry, as single stakeholder, will take all efforts to reduce the production costs, increasing the profit margin. The willingness of industries to actually invest in cleaner production is, therefore, particularly apparent when the industry is 1) forced to pay for its environmental discharges and/or 2) can economically benefit from its investments. In the urban water chain the situation is completely different as water changes from owner along the chain. Each "owner" is responsible for a small piece of that chain of which the borders are set by legislation and legal liability. The "temporary owner" of the water is responsible for the quality of the water that is delivered to the next "owner", which makes it a complex situation. So, where to start?

In order to become aware of the water abuse in the current urban water chain we need to go back to the water-scarce countries, where water availabilities will drop to 50-150 $m^3.person^{-1}.year^{-1}$. In our Western urban concepts the domestic use only is about 50-100 $m^3.person^{-1}.year^{-1}$, reaching values to 200 in USA. Conclusion: copying the Western approach to this region is simply not possible owing to a lack of water! This, apart from the required huge investments for civil constructions related to conveyance systems, centralized services, etc. The minimum flow requirements in conventional sewerage system, already requires water injection in cities like Damascus. Obviously, in addition to domestic use, the available water resources are also needed for agriculture and industrial developments... Therefore, the water-born sanitation and sewerage concept should be carefully re-evaluated for their usefulness in developing countries and water scarce countries in particular. Alternatively, source oriented sanitation (SOS) offers the possibility to recover resources from human/urban wastes without spillage of excessive amounts of water. The introduction of a vacuum collection (toilet) and transport system in a neighbourhood in Sneek, The Netherlands, serving 32 houses, resulted in drop in the per capita water consumption from about 50 to 25 $m^3.year^{-1}$! By collecting and transporting black water and kitchen waste with a minimum volume of water via a small bore vacuum pipe, about 90% of the N, 70% of P, and 70% of organic matter produced in the household, are collected in about 5% of the mean Dutch domestic water flow (Zeeman et al., 2007). The resulting high concentrations of organic matter, facilitates biogas production for energy recovery. Moreover, the concentrated waste offers the potential to recover the nutrients and stabilised organic matter for agricultural purposes!. Anaerobic treatment and nutrient recovery of the black water, now demonstrated in Sneek, shows interesting perspectives for large scale replication.

As all pharmaceutical residues (Lienert, 2007) and estrogens, as well as the largest part of the pathogens, are also contained in the concentrated black water stream, implementation of a specific post-treatment technology, like ozonation, becomes feasible. Whereas black water represents an interesting potential for energy and nutrients recovery, the remaining grey water, composed of shower-bath-, kitchen-, and laundry-water, represents a reuse potential for energy (Elmitwalli and Otterpohl, 2007) and *clean water* for e.g. agricultural purposes. The total energy saving in comparison to conventional sanitation, amounts to 200MJ.person^{-1}.year^{-1}, when applying a community-on-site sanitation concept, based on source separation with black water vacuum collection and anaerobic treatment as the core technologies (Table 1).

Table 1 Energy production, consumption and savings, applying source oriented sanitation in comparison with conventional sanitation.

Action	Utility	Energy	Energy $MJ_{electric}.p^{-1}.y^{-1}$
Biogas production (from black/gray water + kitchen waste)	Waste(water) treatment	10,5 m^3 $CH_4.p^{-1}.y^{-1}$ = 374 $MJ.p^{-1}.y^{-1}$	[4]131
Energy consumption	Vacuum transport	[1]-25 $kWh.p^{-1}.y^{-1}$	-90
	Kitchen waste-grinders	5 $kWh.p^{-1}.y^{-1}$	-18,0
	Post- treatment		[3]-43
Energy saving	Sewage treatment	[2]24 $kWh.p^{-1}.y^{-1}$	86
	Conventional sewer	[6]30 $kWh.p^{-1}.y^{-1}$	108
	[5]Drinking water	[1]0.5 $kWh.m^3_{produced}$	26
Total			**200**

[1]Otterpohl, 1997; [2] CBS, 2002; [3]assumed to be 50% of the energy use at conventional sewage treatment plants; [4]assuming an electrical efficiency of 35%; heat is used for heating the digesters content to 30ºC. [5]Vacuum collection and transport results in 14.6m^3 water saving.p^{-1}.y^{-1}; [6]calculated based on (Leidraad-Riolering, 2002) with 0.08 €.kWh^{-1}

Moreover 0.14 kg P.person^{-1}.year^{-1} as struvite (e.g. NH_4MgPO_4) and 90 l.person^{-1}.day^{-1} of potentially reusable water are produced (Zeeman et al, 2007) .Obviously, the community on-site approach also prevents the need for construction of the mentioned centralised sewerage & services systems.

At several locations in The Netherlands urine separation projects, using urine diverting toilets, are started. As urine contains the major part of the nutrients and about 70% of the pharmaceuticals and hormones, separate collection of urine, as part of an existing sanitation concept, can energetically relieve the existing sewage treatment plant. Moreover, separate collection of urine prevents the spreading of pharmaceuticals and hormones in the environment and it facilitates nutrients recovery. Although the treatment of urine has been extensively researched within the Novaquatis project at EAWAG, Switserland and by Wilsenach (2006), it is not yet applied on a demonstration scale (Maurer et al, 2006). In a complete decentralised concept, the separation, transport and treatment of three streams, i.e yellow, brown and grey water, probably becomes too complicated, unlike urine can directly be used in agriculture as a fertilizer.

The above examples illustrate possibilities to minimise the consumptive use of water in industrial and domestic activities. However, urban waters, preferentially collected in a decentralised mode, additionally can be used for agricultural production and/or for city greening in the (peri)urban area prior to final discharge to surface waters. The urban water chain then becomes intertwined with the agricultural water supply. This multiple water use in the (peri)urban setting offers many advantages such as, the guaranteed availability of irrigation water, the productive use of 'urban nutrients', potential cost-optimisation in wastewater treatment as part of the treatment can be mitigated to the agricultural field. With the growth of the megacities, food production increasingly occurs in the (peri-)urban areas. In fact, in many African cities over 70% of the crops consumed in the city are cultivated in the urban area, whereas > 10% of the world population already consumes products irrigated with partially treated or non-treated wastewater. So far, in developing countries, this practice is ignored or denied. However, by recognising the role of (peri)urban farmers in the city food production, making use of the available water, an overall optimisation of the urban water chain is possible. A town of 1 million people produces sufficient water to cultivate an area of 2000 ha, assuming a per capita urban water consumption of 100 l.day^{-1}. The major constraint in irrigation with treated wastewater focuses on human health hazards, with emphasis on the fate of pathogens. Also environmental issues play a role, such as the fate of excess nutrients, e.g. outside the season, and the fate of micro-pollutants, although these problems are worse if the non- (or partly) treated wastewater is not used in irrigation. In the arid climate zones of industrialised countries these constraints are addressed by implementing extensive centralised treatment systems that eliminate the mentioned health and environmental hazards (e.g. Asano, 1998), which is a logic consequence of how the urban water chain is organised. In developing countries, however, the logistic and financial constraints limit the construction of extensive sewerage and advanced sewage treatment systems, leading to urban drains and the illegal use of the non-treated water for food production; a complete paralysed situation (Van Lier and Huibers, 2007). A breakthrough in this status quo can only be expected by following an *acceptable risk* approach, where *decentralised collection and treatment systems* are coupled to *decentralised use of urban effluents*. In addition to optimised urban water usage, it also results in cost-optimisation both at the treatment site (e.g. no or limited nutrient removal is required) and at the farmer's site (reduced costs for fertilisers). Cost-effectiveness is a prerequisite for rapid and multiple implementation.

Conclusions

The abundant and cheap resource *water* becomes of vital importance when access to clean fresh water resources becomes limited. Optimisation in water efficiency in industrial and domestic activities will increase the per capita water availability. Decentralisation and reuse of treated urban waters for agricultural production will further optimise the productive use of a scarcely available resource.

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Integrated technologies for soil, sediment and groundwater management in industrialised delta regions

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Introduction. Worldwide, industrial hub areas are generally located in low-land floodplains and river deltas. A close position to harbors and other adequate infrastructure for bulk transport over seas, rivers, railways, roads, and airports is the main reason for this. The associated high human population densities, put challenges to maintaining a healthy living environment. At the same time, these delta regions represent often high quality and highly productive agricultural lands that are essential for maintaining the world's food production. Their fresh and brackish water-soil interfaces contain precious ecological habitats to be protected.

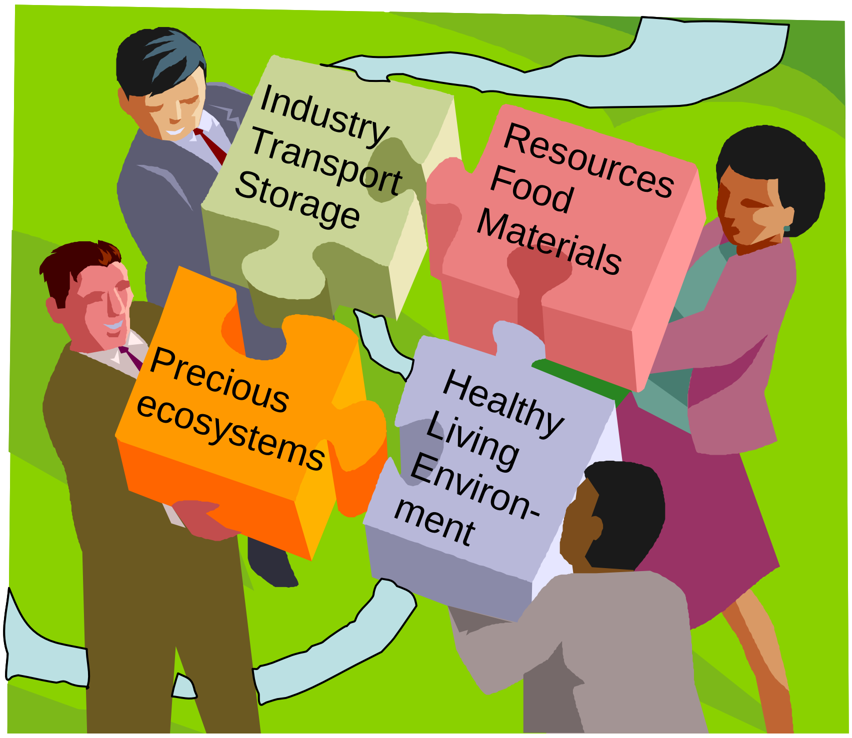

Figure 1. Four important soil-water functions in industrialized river delta regions

So many different soil-water functions need to be maintained in such Delta regions, creating a socio-economical drive to protect each m^2 of ground and each m^3 of soil or water. Soil, sediment and groundwater protection and conservation have therefore been given a high priority, even to such an extent that these media are considered as systems on their own with intrinsic values to be protected and maintained. This type of “singled-out” environmental management has led to inefficient approaches, often neglecting or even wasting positive contributions of the soil-groundwater-sediment system to maintain or restore above mentioned functions. We therefore promote another and more integrated approach; we see soil, sediment and (ground)water systems as reactive media that can be used to sustain the above mentioned functions, and that novel system integrated environmental technologies can and need to be developed that are based on that principle. For the future this new approach is even more needed than at this very moment, in order to adequately cope with increased pressures on land because of increased world population, changed land-use and the need to mitigate and adapt to the effects of climate change. For each of the functions, examples of integrated approaches and associated technology development are discussed below.

Function 1: *Industry, Transport, Storage*

New risk-based approaches have been developed for managing (ground)water contamination at so-called megasites, and the EU FP5 project WELCOME delivered an important contribution to this (Rijnaarts et. al, 2004; Malina et al., 2006). These approaches generally consist of several steps, including: building a conceptual model, assessing the contaminant situation and natural attenuation potential for the entire area, predicting the current and future impact to the surrounding water systems at a large scale and defining optimal risk management strategies to comply towards national and EU directives. The generic approach and the results of four case studies can be found on the project website (Rijnaarts et al., 2004). The results for the Rotterdam Harbor Area are briefly discussed below.

Rotterdam Harbour Area. The Rotterdam mainport is situated at the delta of the rivers Rhine and Meuse and covers an area of 10,500 acres, which makes it one of the world's largest harbours. The main activities that are taking place are the transhipment and processing of bulk goods such as oil, chemicals, coals and ores. As a result of the long-term presence of these industrial activities the soil and groundwater have become contaminated. This contamination is substantial, complex and not limited to one particular site but affects (ground)water systems at a regional scale**.**

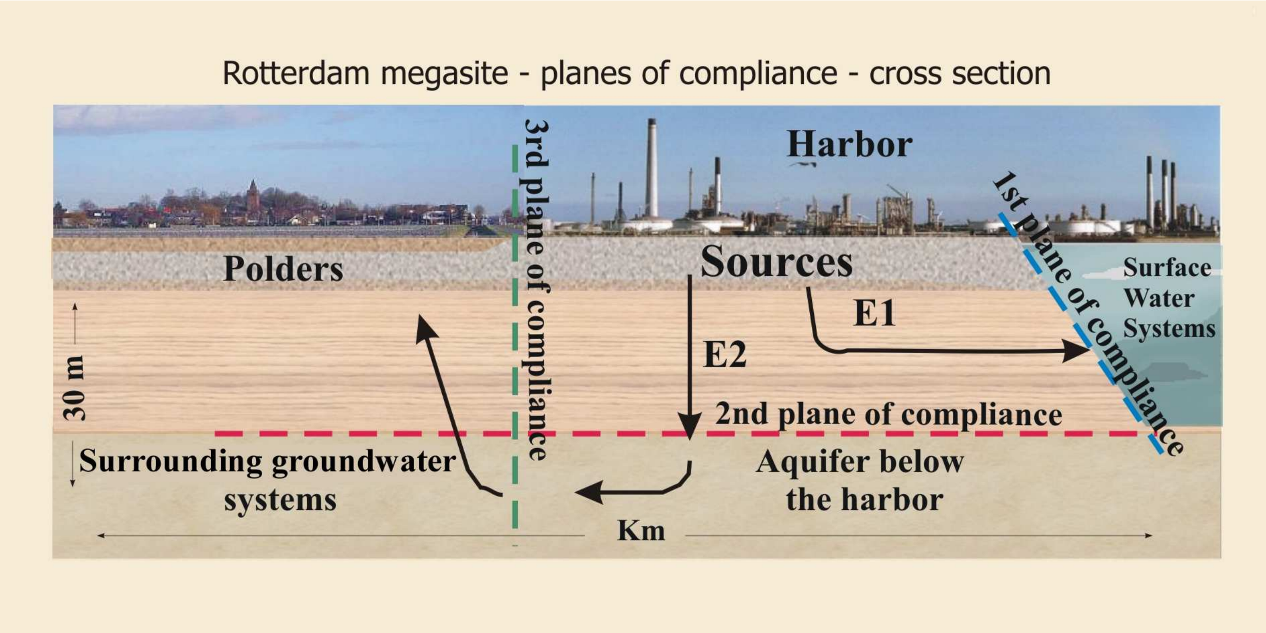

Figure 2 *Conceptual model for the Rotterdam megasite, including contaminant sources, pathways and receptors, as well as the planes of compliance. These planes of compliance are use to set local quality standards to comply with EU and national environmental directives.*

For this area, and the current situation, an integrated system approach has been developed (Ter Meer et al., 2004). The impact of the contamination to the surface water system as a whole is limited and water quality remains below Water Framework Directive quality standards (Van der Wal et al,. 2003). In contrast, the deep aquifer beneath and inland from the harbour area is significantly impacted (Figure 2). Mitigating measures are needed to clean-up and prevent further spreading of contamination into that groundwater system. Natural attenuation and enhanced natural attenuation source-, path- and receptor-oriented measures were found to be most cost-efficient.

New research needed. What the effects are of changing climate and land-use conditions (peak/drought events of river Rhine/Meuse; sea-level rise) is not yet included in the regional risk assessment and management plan. Future studies are therefore needed to address two major items:

1. Include climate change/extreme events (floodings as a result of high river discharges, droughts in heat wave seasons) in the risk assessment and the regional site management plan
2. Develop and integrate technological solutions as part of the management plan. Likely technologies are i) the regional pollution control in groundwater by Monitored Natural Attenuation, ii) thermal use of (polluted) groundwater, to reduce thermal effects on surface water (droughts, heat wave seasons), and iii) eco-bufferzones within the concept of “Safe Greenport”. These buffer zones in water and on land are designed to capture particle associated pollution, to enhance ecological diversity and to provide additional safety towards flooding.

Function 2: Precious Ecosystems

Sediments in river systems are on the one hand needed as carrier of nutrients and spore elements essential for aquatic ecosystems. On the other hand these solids often store strongly adsorbing pollutants. It is often a delicate discussion for decision makers how to prevent damage to an ecosystem while at the other end measures to reduce risks and remediation are needed. In many cases the use of the concepts of bioavailability and natural attenuation can contribute to a better and balanced decision making.

The River "Hollandsche IJssel". In the Rhine/Meuse coastal area several precious ecosystems can be found, that have been impacted by pollution. A typical example is the River the Hollandsche IJssel with fresh water tidal characteristics. On the one hand there is a drive to protect specific nature related to the fresh water tidal areas. For example the partly floating plant Caltha palustris subsp. Araneosa can be found at the boarder of the tidal area. On the other hand, it is one of the most contaminated rivers in The Netherlands, as it is situated in the vicinity of the Rotterdam Europort-Botlek area, a heavily industrialized area. During the period 1950 – 1980, various industrial wastes have been dumped along the river beds, leading to contamination of the sediment by a cocktail of heavy metals, PAHs, PCBs, mineral oil and pesticides like 'drins'. Also, local uncontrolled wastewater discharges have contributed to the contamination. (Grotenhuis et al, 2001). A revitalization program called 'Hollandsche IJssel Cleaner and Better' was started in 1996 to partly remediate the contaminated sediments and adjacent dump sites over a distance of more than 20 km, within a period of 14 years (http://www.schonermooier.nl). Besides the execution of traditional remediation actions, a field study was performed at the location Yacht Harbor Capelle a/d IJssel to assess the potential for in-situ remediation of sediments. As only limited effects of heavy metals can be expected at location Yacht Harbor Capelle a/d IJssel the organic contaminants were chosen to assess the potential for in situ remediation of sediments. Here special focus was on the bioavailability assessment of PAH to underpin management decisions related to dredging versus the use of Natural Attenuation (NA) for the PAH contamination. Results showed that the low availability of the PAH in the river banks allowed the use of Natural Attenuation. Whereas the concentrations and availability in the sediment in the main water way were high, dredging had to be applied here. By this combined approach the specific red list plant species, mentioned above, could be preserved, whereas the environmental risk was minimized.

Sediment quality in European River Delta's. Natural Attenuation in sediments in delta areas and river systems can help to reduce remediation costs as well as play a major role in risk reduction. This principle is studied for 5 river systems in Europe in the Aquaterra project (Gerzabek et al, 2007). In the Ebro river (Spain) nonylphenol showed to be a major contamination in the whole stream area. (Petrovic et al, 2002, Lacorte et al., 2006). Nonylphenol is mostly used as an intermediate in the production of nonylethoxylates which are used in cosmetics and in household cleaning products as a surfactant. This compound has estrogenic properties and is hardly degradable under anaerobic conditions and is therefore looked upon as a priority pollutant. Risks based on total concentrations and estrogenic activity overestimate risks for the environment, as was shown by combined availability and estrogenic activity tests (De Weert et al, 2007). These concepts will be taken into scenario studies mimicking possible situations in rivers (normal base flow, extreme events), in order to better assess the environmental risks of sorbing estrogenic pollutants in rivers.

New future technologies. In availability studies the role of black carbon seems to play a major role in binding of organic contaminants leading to reduction of bioavailability and therefore reducing risks (Koelmans, Jonker et al. 2006). The ageing of hydrophobic organic contaminants seems to be related to the presence of natural occurring soot particles in the environment. These phenomena open up a new approach for a more adequate risk assessment and also to remediation measures based on the use of black carbon and other sorbents in enhancing the binding of contaminants in natural environments.

Function 3: *Resources, Materials, Food*

In the coastal area of the Netherlands, many organic rich agricultural lands are subjected to subsidence. These soils have now an important agricultural and ecological function (protected Bird Habitats), and provide open and green space for recreational activities for the citizens of region. Originally, until 500 years ago, these soils grew from peat moors in a situation where water tables were close to the surface. Frequently these areas flooded and sediments from rivers were deposited on land. Since the anthropogenic formation of polders, where water was pumped out of the area and water tables decreased, oxygen entered the subsurface. Thus, the peaty soils started to oxidize, loosing the organics (>80% of the soil mass) to significant CO_2 emissions. Moreover, the natural addition of sediments to the land by flooding also stopped, due to dikes at the shores of rivers and the sea (Van der Meulen et al, 2007). The resulting subsidence is now in the order of 2 – 5 meters, depending on the local situation. With rising sea levels due to climate change, the difference between sea and land surface levels becomes too large to maintain the land function without taking drastic measures. Basically there are two options: i) let the water re-enter to restore natural peat formation and prevent further oxidation, or even flood the area totally or ii) elevate the land surface in a sustainable way. The political trend is to choose for option i), because there seems to be no feasible alternative. Below we make clear that option ii) may be technically possible and can offer a more sustainable approach, in terms of maintaining agricultural, ecological, an recreational functions, and in reducing greenhouse gas (CO_2 and CH_4) emissions. We have given this approach the name REPE**AT.**

REPEAT: new technology for reversing subsidence of peaty soils. The principle is to re-use all materials in the region of these peaty lands, i.e. manure, dredging sludge from local ditches and canals, and organic waste from various origins, namely form agriculture (straw, beat and corn remains), domestic sources (vegetables, fruit, garden) and from local maintenance authorities (wood, leaves, grass, etc.). These materials can be processed either by composting, anaerobic digestion, or combined technologies to produce non-reactive residual organic rich materials that can be spread over land thus compensating the soil subsidence. The annual subsidence is 8 mm per year, which means that a soil volume of 80 m3/ha per year needs to be compensated. Assessment of regional mass flows for manure, organic waste and dredged sediments, showed that enough residual materials can be produced to compensate for 100 – 200% the subsidence, and that therefore even a gradual elevation of the soil surface can be achieved (Olie et al., in preparation). Crucial elements in the feasibility of the technology are:

i) The environmental and ecological quality of the residual material, thus preserving the quality of the agricultural soils
ii) Density and stability of the residual material to further oxidation under aerobic and anaerobic soil conditions,
iii) Adequate process technology, for controlling environmental friendly and climate neutral processing, i.e. prevent nitrate production and contribute to reduced emissions of greenhouse gasses CO_2, CH_4 and N_2O. Anaerobic digestion including all (organic and inorganic) materials appears to be the optimal technology for larger scale application.
iv) The cooperativety of farmers, nature preservation organizations and local authorities to control the intake and processing of all the masses of materials, redistribute residuals and the subsequent application to the land.

Various projects are being prepared to further investigate the feasibility of REPEAT and related technology in the near future.

Function 4. Healthy Living Environment

In the Netherlands, about 60.000 contaminated sites are scheduled for remediation in the coming 30 years. Many of these sites will be remediated by biological or chemical in-situ treatment. Similar remediation programs will be needed in other European countries, especially after the acceptance of the EU soil directive by the EU parliament, which expected to happen within one or two years.

One important issue is the human health risk before, during and after the remediation. It is known that the soil and especially the vadose zone acts as a reactive interface between surface and subsurface, thus reducing risks to great extents. However, this contribution to risk reduction is not well studied and understood. In delta regions the specific situation of shallow groundwater tables exists and the width of reactive zone ranges between 20 centimeters and a few meters. To better understand risks and processes a new research project was recently started, with chlorinated and aromatic volatile compounds as representative pollutants.

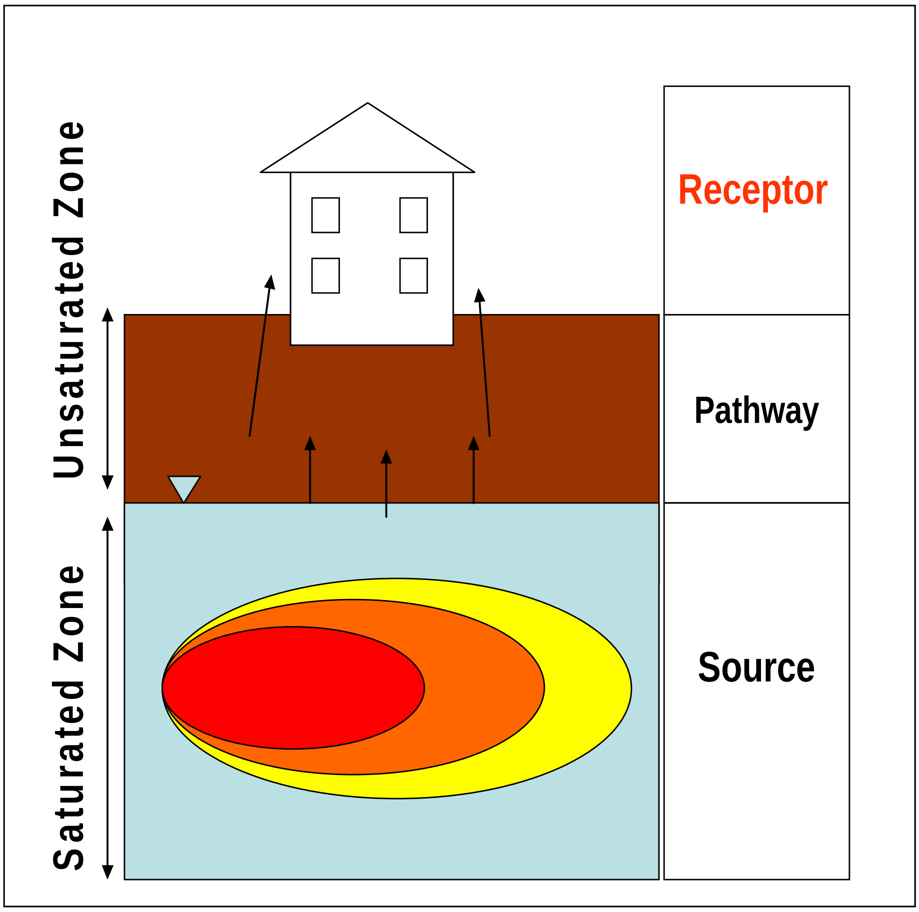

Figure 3. ***Conceptual model for risk assessment of a polluted residential area to be remediated with in-situ methods***

The determination of risks at contaminated sites can be addressed through the Source-Pathway-Receptor approach, and quantified by means of risk assessment models. Vapors of vinyl chloride and benzene, known human carcinogenic compounds, intruding the building from the soil form the most relevant risk for human health at sites contaminated with volatile hydrocarbons. The existing risk assessment model tend to overestimate the concentration of volatile organics in indoor environment due to neglecting possible biodegradation of the vapors in the unsaturated zone of the soil. Moreover, site monitoring data are usually not available for the whole pathway of the contaminant to the receptor. Usually point measurements are conducted, and not over longer time frames. Measurements of fluxes from the saturated zone, to the unsaturated zone and to the ambient air, which can be obtained by passive sampling methods, produce a more reliable estimation of the exposure to contaminants. This research is aimed at filling these gaps.

An integrated monitoring method with passive sampling and continuous monitoring stations will be developed and applied in three European contaminated sites, where the contamination from chlorinated solvents is posing a risk to human receptors. The site have been chosen as representative of different geohydrological and climate conditions in order to evaluate the effects of seasonal variations of atmospheric pressure variations, temperature variations and water level variations on the contaminant migration through the vapour phase. Hot spots zone will be defined as “worst-case” locations in each of the sites. The monitoring undertaken will include: groundwater monitoring with passive samplers, air sampling surveys (passive and active sampling with sorption tubes), continuous monitoring of atmospheric parameters and VOC’s relative abundance in air. Extreme conditions, such as very high groundwater table, atmospheric pressure variations and temperature variations will be also reproduced in the lab and compared with field data and model predictions. The results obtained will lead to improved understanding of the key factors controlling volatile solvent migration from groundwater towards the ambient /indoor air, to better risk models and up-graded monitoring strategies.

Conclusion

The (bio)reactivity of the natural soil-water system was presented as an essential element in new and better approaches for preserving and restoring all four functions important in delta regions (figure 1). Technologies that can be easily integrated into these natural systems are expected to form a new generation of technologies that can be widely applied in delta regions, for sustainable environmental management and for adaptation measures in respond to changes in land-use and climate.

Acknowledgements: The work mentioned was partly supported by the European Union, i.e. FP5 project WELCOME [Water, Environment, Landscape Management at Contaminated Megasites, project no EVK1-CT-2001-00103; www.euwelcome.nl] and the FP6 Integrated Project AquaTerra [Project no. GOCE 505428, under the thematic priority, sustainable development, global change and ecosystems].

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How environmental technology has influenced the position of Dutch consultants over the past 30 years

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In Western Europe, the seventies of the last century have been an important decade for the development of environmental legislation. Taking a look at the developments in the Netherlands, we have seen that during this decade important legislation regarding waste and waste water has come in force. It was the combination of experienced severe pollution of the fast expanding chemical industry and the increasing large scale food processing industry at the one hand and at the other hand the awareness raising on global scale that made us to develop this legislation. As an illustration, at that time there was a first Dutch television course on environment, titled: “Till the shit kills us”.

The global awareness was initiated by the press releases on Love Canal, a serious problem with PBB contamination in an agricultural area, and Silent Spring, the book that described a link between the use of chemicals and their impact on ecology and food chain. It seemed that we had to do something to cope with environmental quality and the effects of chemicals on the long term.

During this episode I was student at Wageningen University in the new field of Environmental Hygiene, the rename of the previous study Waste water treatment. After the demonstrations of students in Paris, students in the Netherlands showed their concern for big items on global scale: war and peace, poorness and food production, North – South dilemmas, industrial development and environmental quality.
This growing public awareness was underlined by the presentation of the scientific report of the Club of Rome, “The limits to growth” in 1972. This booklet, written by Dennis Meadows and supported by the Club of Rome was a first attempt to define the relations between natural resources, industrial production and environmental impact, setting the outlines for global strategies.

As students in Environmental Hygiene, we were proud that we could contribute to the solution of these problems.

Environmental technology was at that time challenging and simple. Challenging as it was seen as a new scientific area that could bring important solutions for the problems we had become beware of. Simple as we basically had two main books that were defining the world of the first environmental technologists: The Dutch book of professor Koot on waste water treatment and the book of Fair, Geyer and Okun on Environmental Technology. Both books mainly dealing with (waste) water technology.

Being graduated in environmental technology it was not a problem to find a job. Already as a student you could make your choice, what job to accept at industry or consultancy. My choice has been consultancy.

The focus of Dutch consultants in the seventies was completely on waste water engineering. There was already a lot of experience, as the Dutch municipalities and water boards started already their efforts in waste water treatment during the fifties. This early developments were initiated by the fact that the Netherlands as a densely populated delta area had been confronted with as well our own pollution as the trans border impact from our upstream neighbouring countries.

During the second half of the seventies the policies were set to treat waste water at the source instead of only by building centralized waste water treatment systems. This policy gave an impulse to the development of more specific waste water treatment technologies, aiming at specific industrial branches. Technologies like separation, physical-chemical treatment, and anaerobic treatment of waste water with a high COD load were introduced in the Dutch market. Wageningen University took the challenge to develop quite a range of technologies for specific types of waste water.

This early and fast adaptation of new waste water technologies offered the Dutch consultants and constructors the possibilities to export their expertise abroad. Projects were initiated in the Caribbean, Middle East and all over Europe.

During the early eighties a new item popped up: soil contamination and remediation.
Shortly after the “Lekkerkerk case” legislation had been developed aiming to get rid of this problem within an ambitious five year period. Shortly after it became obvious that this was not a short term problem. It was not just a matter of dig and dump; this problem required a more serious approach and also technology development.

As soil remediation was seen as an interesting market opportunity, several contractors invested in on site soil remediation technologies. But it was also evident that this was not bringing the final answers. By the end of the eighties the first steps were made to develop in situ technologies for soil treatment. The strong interaction between universities and consultancies has lead at that time to a rapid development of applicable in situ technologies. The combination of contaminant behaviour, transport mechanisms, understanding of conditions for desorption, variability of retention times in inhomogeneous soil types are just examples of sub-items that had to be developed. In the Netherlands the “NOBIS program” was an important enabler for the cooperation between stakeholders.

This close cooperation between universities and consultants has not only led to a range of applicable technologies for the Dutch market, it has also enforced the export position of the Dutch environmentalists.
Till date we are able to contribute in different countries to the development of legislative frameworks, strategies and policies and the corresponding technologies to deal with soil contamination in an adequate way.

As it seems that every society has to find its own ways to deal with environmental problems. Every society has at first to experience the urgency of pollution, has to be confronted with its own Love Canal or Lekkerkerk to make a real start with remediation measures. And it always starts with the visible and “smellable” problems and afterwards with a more integrated approach. For me the main reason for this generic approach is the fact that solving of environmental problems is mainly a matter of investment with no or only a low pay out.

My explanation is found in the triangle of Maslov, although he never mentioned the word environment. The bottom of this triangle has to do with survival, the basic instinct of each human being to survive, to belong to the fittest. When environmental problems have proven to be a threat for human beings, as it was in Love Canal, Lekkerkerk, the Black Triangle in

Central Europe and recently in serious water pollution problems in China, this leads to action. The globalisation of expertise, speeded up by the use of internet is an important trigger for international developments.

Another driver for environmental management is found in the top of the triangle of Maslov. This has to do with ideals and luxury, with quality of life. In Western Europe we see adequate environmental management as an integral part of our well being. The impact of technology on our daily life has to be coped with by technological solutions. We see the investments in environmental technologies as the price to be paid for our well being. The lessons learned over the past 30 years in the stretch between survival and luxury has brought us the understanding how to contribute to sustainable development and good environmental management. Although still in search of better solutions, we have the tool box filled and the technological infrastructure available to deal with these problems.

The last 30 years has been a challenging episode in environmental technology development. Since I met Wim Rulkens for the first time, about 25 years ago, I feel that we have been partners in these developments over this whole period. As well in a front runner position in the Netherlands and Western Europe as also in the contribution to the field of obsolete pesticides in Central and Eastern Europe and Central Asia. It is an honour for me to share this feeling of “environmental technology soul mates”. We have been able to contribute, each from our own position and being aware of the limitations. We have not changed the world; we have had a contribution to improvements. It seems that we can continue to cooperate in these contributions in the years to come. For me it will be again an honour.

Sustainable technology for municipal solid waste treatment in Hochiminh city, Vietnam

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Abstract
The Kyoto Protocol and Clean Development Mechanism (CDM) with Certified Emission Reductions (CERs) market are creating the new opportunity for applying a sustainable technology to treat municipal solid waste (MSW) generated from Hochiminh city, which is containing a large biodegradable organic fraction (60-75% based w.w.) and recyclable materials (up to 25% based w.w.), towards 3R - Reduce, Reuse and Recycle. MSW will be separated into two types: (1) a biodegradable organic fraction which can be digested anaerobically to produce biogas for energy recovery (electricity and heat) and subsequently can be composted aerobically to produce organic fertilizer, and (2) the rest for reuse or recycle. This is a clean technology and many environmental, economical and social benefits can be obtained.

Introduction

Hochiminh city, located in South Vietnam with 2,093.7 km^2, is the biggest city and center of science, technology and finance of Vietnam. With a population of more than 8 million inhabitants (going to be 10 million inhabitants in 2010) living at more than 1.4 million houses, more than 2,000 large factories and 9,000 medium and small enterprises located in 11 industrial parks, 3 import-export zones, one hightech park and 33 industrial areas, 103 hospitals, more than 400 medical centers, ten thousands restaurants, hotels, markets and super markets, etc., Hochiminh city generates 6,500-7,000 ton/d MSW, in which biodegradable organic matter is approximately 61-96% (based w.w.). At present, the collected MSW (5,700-6,200 ton/d) is dumped into the landfills Phuoc Hiep of 822 ha and Da Phuoc of 128 ha. The leachate and offensive smell generated from these landfills are heavilly polluting the surrounding environment. In addtion, it takes about 15-20 ha a year to construct a new landfill.

Fig. 1 Go Cat landfill in Hochiminh city, Vietnam.

Thus, application of the new technology, especially the sustainable technology, is very necessary and it will give significant benefits with respect to environment, economy and society.

Sustainable technology for msw treatment

Composition and Generation Rate

The investigated data since 1996 have shown that food residue is the biggest amount of MSW of Hochiminh city (Table 1), e.g. 60.0-70.0% (based w.w.). The rest, such as paper, plastic, leather, cloth, metal, etc., ocuppies about 20-25% (based w.w), which are separeted and recycled by the city scavengers, approximately 18,000-21,000 persons (CENTEMA, 1996, 2003 & 2006). Rapidly biodegradable organic fractions cause heavy offensive smell after few hours of storage.

Table 1 Composition of MSW in Hochiminh city at landfills

No.	Composition	Phuoc Hiep	Go Cat
1	Food residue	60.0-72.1	67.0-75.0
2	Nylon	11.5-17.0	11.0-13.2
3	Plastic	0.5-1.5	0.8-1.7
4	Cloth	3.6-9.8	3.8-5.2
5	Soft rubber	0.3-1.6	0.9-1.7
6	Hard rubber	0.4-1.2	0.8-3.4
7	Wood	1.2-3.7	2.5-3.1
8	Styrofoam	1.0-4.9	0.4-0.8
9	Paper	2.4-4.0	2.3-3.2
10	Glass	0.0-0.6	0.0-0.3
11	Metal	0.2-1.0	0.2-0.9
12	Leather	0.0-1.0	0.5-1.3
13	Brick, ash, etc.	0.0	0.0
14	Ceramic	0.0-0.1	0.0-0.2
15	Carton	0.0-0.1	0.0-0.1
16	Can	0.0-0.2	0.0-0.3
17	Pin	0.0-0.2	0.0-0.3

Table 2 Generation rate of SMW in Hochiminh city

No.	Year	Generation rate (ton/year)	Generation rate (ton/d)
1	1997	983,811	2,695
2	1998	939,943	2,575
3	1999	1,066,272	2,921
4	2000	1,172,958	3,214
5	2001	1,369,358	3,752
6	2002	1,568,477	4,297
7	2003	1,731,387	4,744
8	2004	1,763,866	4,833
9	2005	1,737,553	4,760
10	2006	1,888,185	5,137
11	2007*	2,017,000	5,800

* Predicted

With a high economical growth rate (12.5% per year), generation rate of MSW increases about 6-8% per year (CENTEMA, 2006). The data is presented in Table 2. The generation rate of MSW in Hochiminh city is stable during Tuesday to Saturday, e.g. 5,700-5,900 ton/d, and it slightly drops on Sunday and increases on Monday, e.g. 6,200-6,500 ton/d. Especially, during National New Year it rises up to 10,000-12,000 ton/d.

Due to the high biodegradable organic fraction and huge amount of MSW, a big volume of landfill gas (LFG) generates from existing and closed landfills in Hochiminh city. The LFG, containing a high fraction of methane gas (55-65% based volume), can be used for enery recovery, such as electricity and heat, and for CER (Certified Emission Reduction) exchange in the global market.

In the case of Hochiminh city, the following sustainable technology for MSW treatment toward 3R (Reduce, Reuse and Recycle) is suggested (Viet & Dieu, 2006) and presented in Figure 2. According to this technology, MSW will be separated into biodegradable organic matter and recyclable or reusable materials. The recyclable or reusable materials can be used as raw materials for other industries after pre-processsing. The biodegradable organic matter will be anaerobically digested to produce biogas, which can be used for energy recovery and CERs exchange, and then after reducing humidity (using heat or sunlight) the digested products will be aerobically processed to produce compost and organic fertilizers. Organic fertilizers can be used as a landfill cover material, for organic vegetable producing areas, cashewnut areas, etc. This is the first priority technology to be selected for MSW treatment in Hochiminh city.

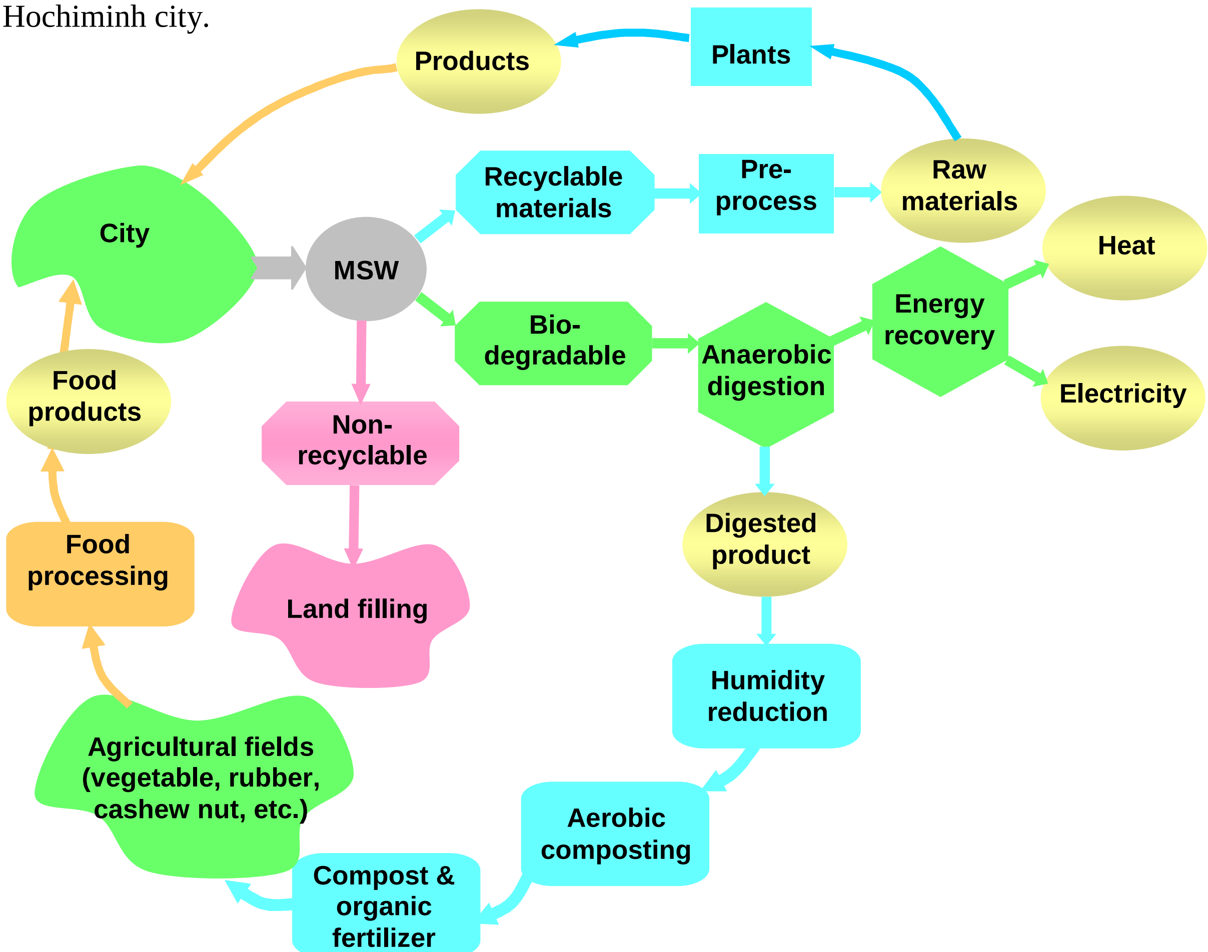

Fig. 2 General schema of sustainable technology for MSW treatment in Hochiminh city, Vietnam (Viet & Dieu, 2006)

Conclusions

In the circumstances of Hochiminh city,where a huge amount of MSW is generated and the landfills are causing heavy pollution, proper management and selection of a sustainable technology for MSW treatment toward 3R play a very important role.

Biotechnology in combination of anaerobic and aerobic processes will meet the environmental, economical and social requirements. In order to apply the technology, financial support and promotion policy play very important roles.

Acknowledgement
This paper was prepared as our compliments Prof. Dr. Wim Rulkens on his farewell anniversary to mark his valuable contribution to the great achievements on education and training of human resources for environmental field.

Bài viết này được thực hiện như một lời chúc mừng đến GS. TS Wim Rulkens nhân ngày kỉ niệm kết thúc một giai đoạn đóng góp vào sự nghiệp đào tạo nhân lực ngành môi trường.

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Environmental Application of UV Photochemical Technology in China

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1. Introduction

Photons with ultraviolet wavelength, particularly UVC (180 – 280 nm), have the energy that match with various bond energies, and can be adsorbed by many molecules and microorganisms. The energy of photons can be calculated by equation (1):

$$E_\lambda = \frac{hc}{\lambda} A \qquad (1)$$

Where,
E_λ, the energy of photons with wavelength λ, kcal/Einstein.
c, the speed of electromagnetic wave in vacuum, 3.00×10^{17}nm/s
h, Planck constant, 1.583×10^{-37} kcal·s
λ, wavelength of photons, nm
A, Avogadro constant, 6.023×10^{23} photons/Einstein

The calculated energy of UVC with wavelength of 180 – 280 nm is between 159 – 113 kcal/Einstein. Table 1 gives various bond energies in organic compounds and also in microorganisms.

Table 1. Important chemical bond energy

Chemical Bond	Bond Energy（kcal/mole）
O-H	110-111
C-H	96-99
N-H	93
C=O	173-181
C-N	69-75
C=C	146-151
C-C	83-85

Obviously, the photons with UVC wavelength occupy enough energy and a capability splitting the chemical bonds shown in Table 1, further, initiating possible chemical reactions. This characteristic of UVC has been widely used for the destruction of various chemicals and microorganisms for our environment protection.

A special UV lamp can be made from little amount of mercury (a few mg to 1 gram), which the UVC output approaches 40% of total energy input. The application of amalgam makes

UV lamps possible with high power (500W), high efficiency (35%), stable working in low and high temperature (3 – 60 ^{o}C), and a long life around12,000 hours with less 20% UVC depression.

2. UVC Disinfection

UVC, specially the wavelength of 254 nm, is the most sensitive wavelength for various pathogens. It induces the formation of dipolymers of some of components in DNA, causing that pathogens can not duplicate themselves, or breaking bonds in DNA directly. Table 2 shows the requirement of UV dose for the deactivation of various pathogens.

UV dose (254 nm) required for a 90%(one log) deactivation of various microorganisms

Bacteria/virus	Dose(mJ/cm2)
Bacillus Subtllis (Spores)	5.80 / 7.10 (12.00)
Corynebacterium Diphtheriae	3.75
Dysentery Bacilli	2.20
Escherichia Coll in air	3.00
Escherichia coll in water	5.40
Leptospira SPP (infectious Jaundice)	3.00
Legionella Pneumophila	2.04
Micrococcus Candidus	6.05
Salmonella Enteritidis	7.60
Serratia Marcescens	2.42
Shigella Dysenteriae (Dysentery)	4.20
Staphylococcus Aureus	2.60
Streptococcus Haemolyticus (A)	6.70
Sreptococcus Salivarius	2.00
Tuberculose Bacillus	10.00
Vibrio Comma	3.10
Hepatitis B Virus	11.00
Poliovirus	12.00
Influenza	3.40

With the up to 40% high efficiency UVC lamp that appeared in the 1980's, UV disinfection has been widely used for water disinfection, especially for municipal wastewater. About 40 pieces of 240 W amalgam lamps involve in the disinfection of 10,000 m^3/day wastewater (BOD 20, COD 60, SS 20, T_{254} 65%), approaching dose of 15mJ/cm^2, and at least 3 log deactivation of E. coli.

Since new rules of municipal wastewater discharge has been in valid in 2006, around 200 Wastewater Treatment Plans have been installed UV disinfection system in China. Newland has installed 120 WWTPs, which shares more than 50% of the market.

3. UV Photochemical Deodor of WWTP, Trash Station and Chemical Plant

UVC deodor system is efficient, low cost, convenient for odor elimination. In China, the issue of odor is present almost everywhere in eastern coast WWTPs, trash transfer stations and chemical plants. A large amount of complaints to the local government came from the residents living around bad smell points. However, after installing the deodor system, the number of complaints decreased dramatically.

Main compounds in odor of WWTP are ammonia, hydrogen sulfide and organic sulfides (e.g. methanethiol, ethanethiol). The possible elimination mechanism of odor is mainly via following initiation processes.

$$O_2 \xrightarrow{UV184nm} 2O\bullet \qquad (2)$$

$$O_2 + O\bullet \rightarrow O_3 \qquad (3)$$

$$NH_3 \xrightarrow{UVC} NH_3^* \qquad (4)$$

$$NH_3 \xrightarrow{UV184nm} \bullet NH_2 + H\bullet \qquad (5)$$

As shown in equation (2) to (5), a lot of very active components such as free radicals, excited molecules and oxidants are formed during the irradiation of UVC. Obviously, further oxidation of bad smell, NH_3, H_2S, CH_3SH and BTX etc. can be processed promptly with these active components. Such process is called “Advanced Oxidation Process” (AOP), which is a new technology in environment protection. Fig.1 to Fig.4 gave the data of odor degradation tests.

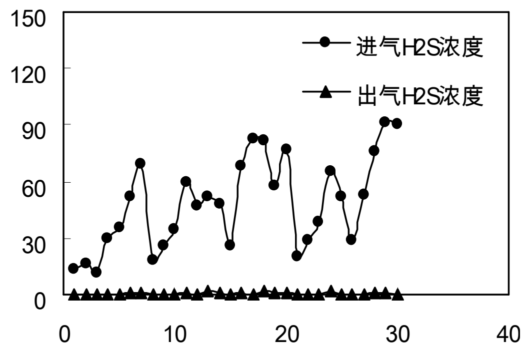

Fig.1 H2S UVC degradation in a WWTP

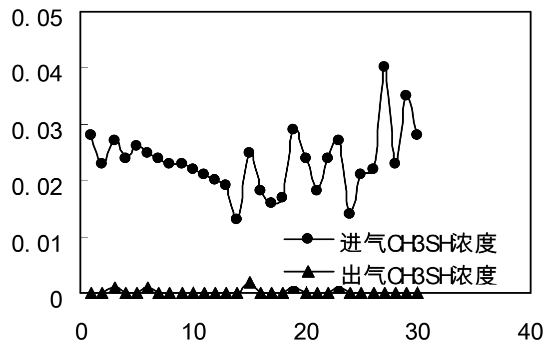

Fig.2 CH3SH UVC degradation in a WWTP

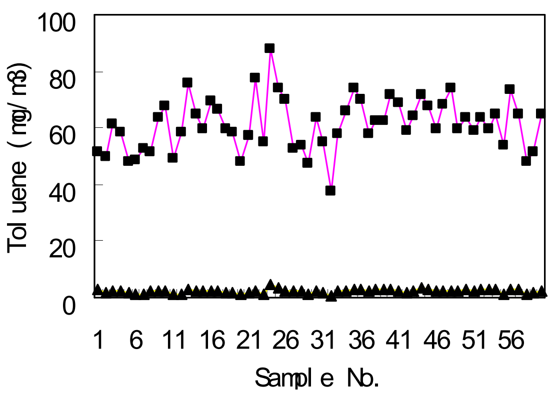

Fig.3 Toluene UVC degradation in a painting

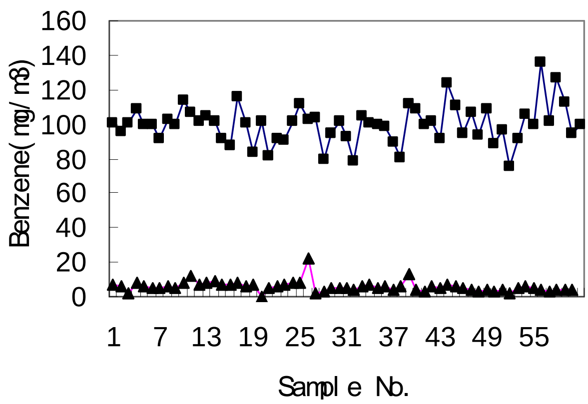

Fig.4 Benzene UVC degradation in a painting

The data of Fig.1 to Fig.4 were obtained from a full scale UVC deodor system in a Beijing WWTP and from a painting plant in Fuzhou (odor gas flow rate: 5000 m3/h; UVC lamps: 40WX30 pieces; UV reaction chamber: 2000X1500X1500mm).

With the association of UVC, many reactants can be activated (equation (4)), or oxidants can be split to form free radicals (equation (2)). Ozone is a strong oxidant, but its oxidation reaction is still very slow comparing with OH radical. Table 2 gives the reaction rate constant of ozone and OH radical. It's clearly that the reaction rate of OH radical is at least million times faster than ozone.

Table 2. The constant of reaction rate of ozone and OH radical

Compounds	K_{Ozone} ($M^{-1}s^{-1}$)	K_{OH} ($M^{-1}s^{-1}$)
Aromatics	1 to 10^3	10^8 to 10^{10}
Benzene	2	5 x 10^9
Toluene	20	5 x 10^9
Xylene	100	5 x 10^9
Phenols	10^3 to 10^5	10^9 to 10^{10}
Phenol	1.3 x 10^3	5 x 10^9
Amines	0 to 1	10^9 to 10^{10}
Alcohols	10^{-2} to 1	10^8 to 10^9
Methanol	2.4 x 10^{-2}	10^9
Ethanol	0.37	10^9
Carboxylic Acids	10^{-5} to 10	10^7 to 10^9
Acetic Acid	3 x 10^{-5}	2 x 10^8
Chlorinated Aliphatics	10^{-4} to 10^2	10^7 to 10^{10}
Carbontetrachloride	5 x 10^{-3}	1 x 10^7
Tetrachlorethylene	0.1	3 x 10^9

4. Conclusion

UVC technology is an alternative disinfection method for chemicals, and has been applied for wastewater disinfection. It protects our water environment from secondary pollution by chemical disinfection. UVC photochemical technology, which is one of AOP technology, is a method with high efficiency, low cost and convenience for the degradation of low concentration gaseous organic or inorganic compounds. In the presence of UVC, a lot of gas oxidation reactions are accelerated significantly due to the production of supplementary free radicals, which it has been widely used for various odor eliminations in our daily life.

Environmental risk reduction at postindustrial areas in Poland

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Introduction

Long-term diverse activities in industrial areas of Poland resulted in direct emissions of waste products into the environment. These have resulted in diffuse pollution on a mega-scale (e.g. brownfields, post-industrial areas, military bases, etc.), which makes the active conventional remediation within an intermediate timeframe not feasible, or even impossible for technical and economical reasons (Malina et al., 2006). Such areas are, therefore, continuous and long-term potential and actual sources of regional contamination of soils, surface water, groundwater and/or sediments. Moreover, they respond much slower to remediation measures than other environmental compartments, thus need more time to improve their quality. Shifts in environmental policy observed since the mid nineties from multi-functionality into the risk reduction for humans and ecosystems to acceptable levels resulted in changing remediation goals from target-oriented into risk-oriented (Malina, 2005).

Postindustrial areas are defined as degraded, contaminated, and either abandoned, or not fully used areas previously designated for industrial/business activities that have been terminated (Program Rządowy ..., 2004). These areas (excluding these having military or agricultural functions) are degraded to a degree that limits the possibilities of development and/or returning to their previous economic functions. The integrated management approach is required for postindustrial areas, which in particular, should take into account soil, surface water and groundwater quality protection, including information systems (monitoring, reporting, research and development (R&D)), as well as criteria and activities required for implementing it. Risk related to humans, and correlation between degraded area and economy should also be considered.

The European framework

Although the EU has no contaminated land legislation, some directives have an impact on the requirements for national legislation and policy on soil protection and/or remediation, and are particularly relevant: (i) *Waste Framework Directive* (2006/12/EC); (ii) *Hazardous Waste Directive* (1994/31/EC); (iii) *Landfill Directive* (1999/31/EC), (iv) *Water Framework Directive* (2000/60/EC); (v) *Groundwater Directive* (2006/118/EC); (vi) *Integrated Pollution Prevention and Control Directive* (1996/61/EC); (vii) *Directive on management of waste from extractive industries* (2006/21/EC) (amending Directive 2004/35/EC); (viii) *Strategic Environmental Assessment Directive* (2001/42/EC); (ix) *Drinking Water Directive* (1998/83/EC); (x) *Directive on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community* (2006/11/EC).

Some other relevant documents include: COM(2006) 231 and 232, and SEC(2006) 620.

Principles of soil/land and (ground)water protection in Poland

The principles of land protection in Poland are given by the: *Environment Protection Law* (Dz.U.2006.129.902), *Law on Nature Protection* (Dz.U.2004.92.880), *Law on prevention of environmental damages and their repairing* (Dz.U.2007.75.493), *the Water Law* (Dz.U.2005.239.2019) and, partially by the *Act on the Waste* (Dz.U.2007.39.251). Based on the first document, the *Decree on Soil and Land Quality Standards* (Dz.U.2002.165.1359) defines when soil is considered as contaminated. It is based on soil standards for the actual and planned land's functions, for the following groups: (A) land included in the areas protected under the *Water Law*, or under the *Law on Nature Protection*, if the actual contamination is not considered hazardous for humans and environment; (B) crop and grasslands, forestlands, barren and urban lands; (C) mining and communication areas.

The main goals of ecological policy from the contaminated land viewpoint in Poland until 2010, as stated in the Ecological Policy Act from 2002, are (Malina, Kwiatkowska, 2006): (i) monitoring of soils, including physical-chemical and biological changes due to erosion, urbanisation, industry, emissions, waste, wastewater, etc.; (ii) identification of risks and intensification of remedial and reclamation actions at contaminated areas; (iii) re-development of post-industrial areas to include them again in the economic cycle, the so-called re-vitalisation.

National program for postindustrial areas in Poland

The *National Program for Postindustrial Areas* approved by the Polish government in 2004 gives the frame for integrated management strategies to be developed to reclaim contaminated/degraded abandon areas. The strategic goal is to create conditions and mechanisms for re-vitalization of post-industrial areas according to the sustainability principle. The direct goals include (Program Rządowy … 2004):

- development of the management system to re-vitalize post-industrial areas, and consequently reduce use of non-degraded areas (i.e. greenfields) for industrial purposes,
- development of sectors engaged in remediation and re-vitalization, thus generation of new jobs.

The Minister of Environment is coordinating the *Program* via the Program Coordinator with the assistance of the Steering Committee. The *Program* tasks introduced in parallel should be complementary, and realized with different strengths under the supervision of Field Coordinators at three fields: (i) pilot revitalization projects; (ii) developing the management system for postindustrial areas; (iii) R&D and education.

The *Act on Spatial Site Planning and Management* (Dz.U.2003.80.717) defines goals and principles of plans development in communes, districts and provinces, based on the sustainability principle. Transferring many rights to local governments creates possibilities of undertaking decisions important for given post-industrial areas.

Effective management of postindustrial areas requires also introducing certain legal changes related to: (i) range and ways of carrying on tests on soil and land quality; (ii) principles and rules of carrying on registers of postindustrial areas, taking into consideration liquidation of industrial plants, mines, hazardous waste deposits, etc., which are recognized as activities having significant impacts on environment; (iii) technical projects of re-vitalization, negotiations and implementation; (iv) creation of financial benefits for potential investors.

Integrated Management for Postindustrial Areas in Poland

Integrated management systems allow for complex examination of the problem, an integrated working plan that includes elements required by different standards, simultaneous inspection of the system and certification process, open access and flexibility for introducing further requirements, and the synergy that rises during cooperation of different elements. They require: programming (i.e. designing the most desired events from a prospective situation viewpoint) and planning (i.e. transcription of goals into tasks and working out the organizational and financial ways of execution). These principles were first introduced in the ISO standards (series 9000).

The sources of specific information for integrated management systems for postindustrial areas are: (i) environmental monitoring networks that provide information comprising air, soil/land, surface and groundwater quality, waste generation and management, etc., as well as predicted results of operational use of the environment on national, regional and local scales; (ii) statistic reporting on activities that impact environmental quality, e.g. reports on hazardous waste, which is the responsibility of enterprises that use the environment directly, and national and local governmental offices; official information should be included in registers of land's evidence and real estate, cadastres of natural resources, maps of soil classification, etc.; (iii) R&D that provides supplement and verification of data from environmental monitoring and statistical reporting.

Concept of the management system. In Poland, the integrated management strategy for postindustrial areas is not yet fully defined, however, for the past few years, studies have been conducted and re-development actions have been undertaken. At postindustrial areas one has to address degradation, which encompasses: (i) environmental compartments (atmosphere, hydrosphere and lithosphere); (ii) societies (illness, unemployment, social degradation); (iii) economy (bankruptcy and/or, re-structuring of enterprises, plants, etc.). Therefore, the integrated strategy should rely on conscious and intentional merging activities aimed in returning degraded areas for reuse, as well as re-structuring economy and managing human resources. These activities must be in agreement with local development plans (communes, districts, etc.), thus, require cooperation with local authorities. This is also important for obtaining funds.

Returning useful properties of postindustrial areas may comprise (Malina, 2007):

- remediation (sanitation) using physical, chemical, and biological methods,
- reclamation (re-cultivation) - actions directed to return natural earth surface/to reach quality of soil according to standards to create/return useful/natural values for deteriorated land,
- re-vitalization (re-development) - land remediation followed by reclamation, change and modernization of earth surface, etc., to return the status of land that allows for fulfilling its useful functions.

The management system for postindustrial areas should include: (i) qualitative evaluation of an environmental status; (ii) diagnosis and assessment of health and environmental risk; (iii) selection of effective technologies; (iv) evaluation of the effects of undertaken decisions on economy and societies; (v) use of research achievements in environmental engineering/technology and ecology; (vi) national, regional and local policies.

Model of the management system. Based on the author's experiences, the model of integrated management system for postindustrial areas is recommended (Fig. 1) (Malina, 2007).

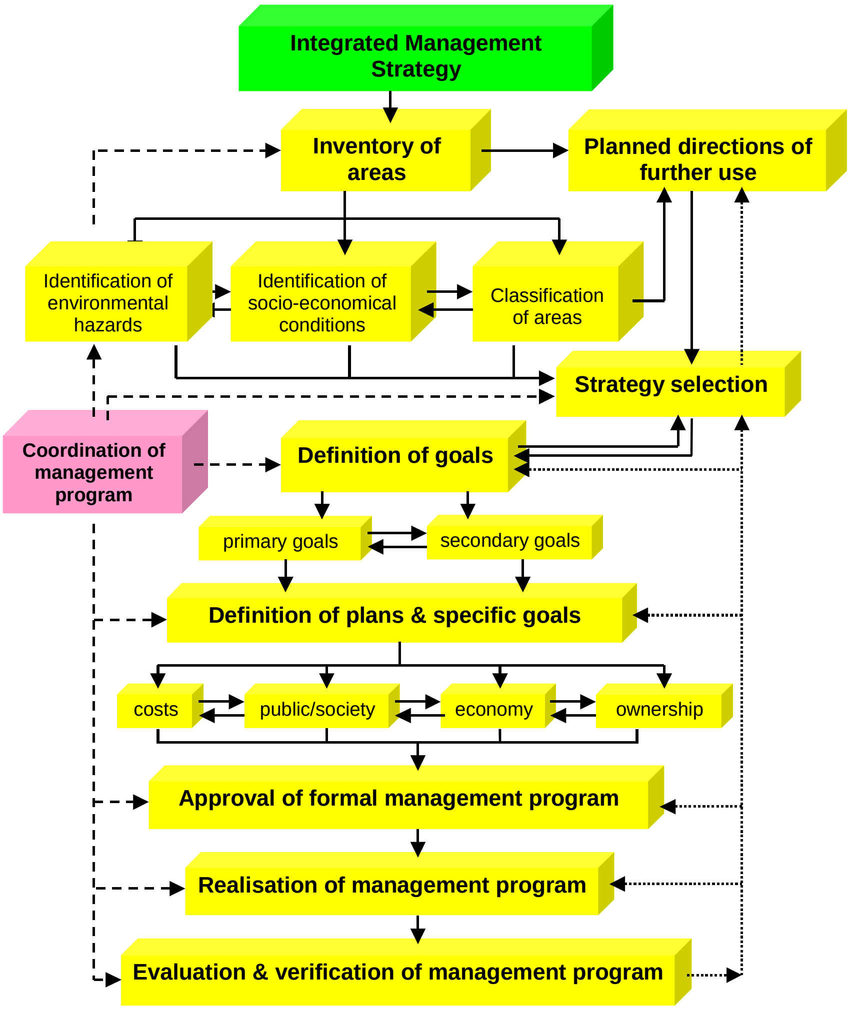

Fig. 1. Model of the integrated management system for postindustrial areas (Malina, 2007)

Concluding remarks

The strategy of environmental risk reduction at postindustrial areas should include: diagnosis of contamination sources and levels, identification of risks (ecological and human), remediation concepts, and risk-based land management approaches for their re-vitalisation. Identification of problems is a prerequisite for developing management mechanisms.

The integrated management strategy for postindustrial areas is based on conscious and intentional aggregation of all actions related to remediation, reclamation and re-vitalization, as well as re-structuring of economy and human resources. It is a long-term and complex process that comprises many fields and requires many tasks and activities to be carried out.

The *National Program for Postindustrial Areas* gives the basis, and formal and legal frame for developing the management strategies to re-vitalize contaminated/degraded lands.

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Biological production of bioenergy

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Biological bio-energy

In our mature economy, the fields of renewable energy and sustainable water have interesting possibilities for revolutionary technological innovations. With the increasing demand for energy (doubling expected in 2050), the price increase of fossil fuels and the threat of global warming, enormous potential for innovation is available in this field. The same is true for sustainable water technology. Water scarcity is threatening billions of people and also new environmental demands in the western world will be very expensive or impossible to meet without new technology.

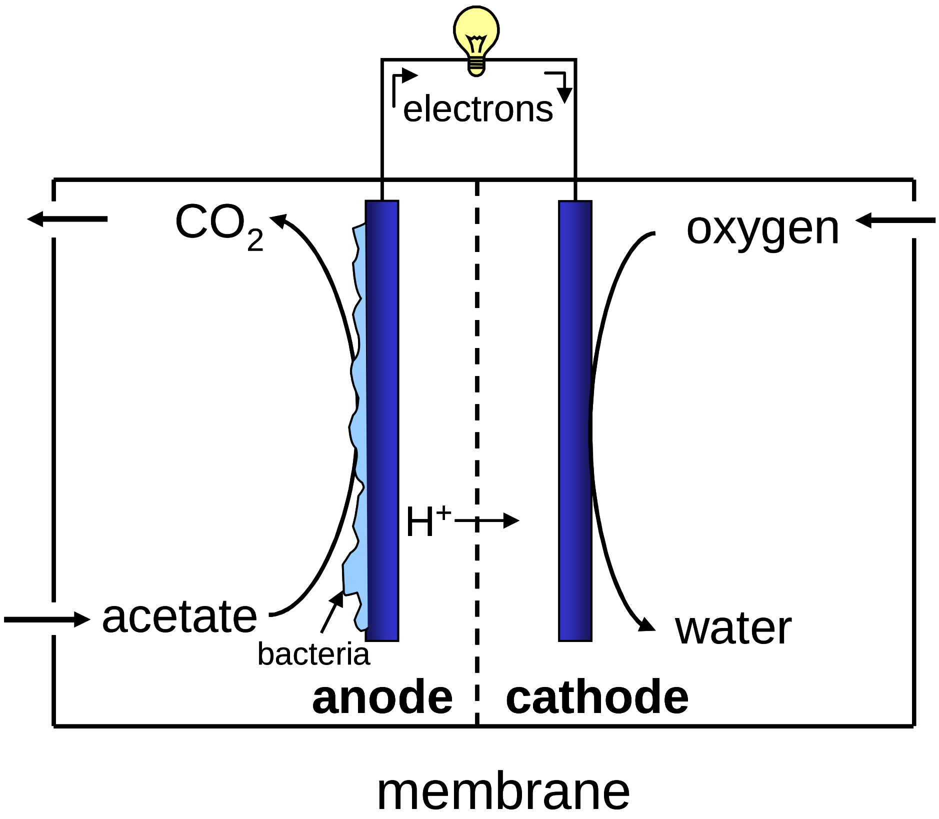
In the past, the water and energy sector were mainly depending on geology, mining and hydrology in which the leading principle was to find and explore resources. Depletion of the oil/gas and fresh water recourses will lead to increasing need for new and sustainable technology. Renewable energy will be based on solar energy in its many forms. Sustainable water will be based on conversion of salt water or water from the atmosphere.

In the future, conversion and separation technologies will be used much more in these sectors than the currently used mining technologies. For these new technologies our department wants to be inspired by nature, which is already able for millions of years to produce clean energy and water in combination with complete recycle and reuse of all resources. An example of this is the biological production of bio-energy. With this we mean the biological conversion of biomass into valuable energy carriers.

The department of Environmental Technology already works in this way for more than 40 years. Our worldwide reputation on anaerobic technology in which biological methane is produced is an example. In the presentation, we want to show you some ideas from our new bio-energy group.

Bio electrochemistry to produce bio-electricity and bio-hydrogen

The microbial fuel cell (MFC) is an electrochemical device in which micro organisms produce electricity from biodegradable material. In this way, chemical energy is converted directly into electrical energy. The MFC consists of two compartments: an anoxic compartment with an anode and an aerobic compartment with a cathode. At the anode, bacteria oxidize organic material to carbon dioxide, protons and electrons. Electrons are released to the anode and go through an electrical circuit to the cathode. There the electrons reduce oxygen, together with protons, to water. Protons migrate from anode to cathode through a cation exchange membrane, which separates both compartments. In the overall reaction, organic material and oxygen are converted into carbon dioxide, water and electricity.



The MFC has become recently a focal point of research interest because of the discovery of the so-called electrochemically active bacteria. These micro organisms are capable of growing while directly transferring electrons to an electrode. This type of biological catalysts is attractive as it is renewable, produced in situ and active at ambient temperatures. Mixed cultures of micro organism can degrade and produce electricity from a vast array of organic compounds present in water.

The organic waste and wastewater generated by households only already equals an amount of 1.3 million tonnes of organic matter (data CBS, 2005). Assuming a projected MFC efficiency of 60% and an average energy content of 15 MJ/kg it can be estimated that 12 PJ of electricity could be generated. This amount is 16% of the total electricity production in the Netherlands.

Using another cathode also hydrogen gas can be produced. In this case no oxygen is added to the cathode. Also a small potential difference has to be applied. In this way fatty acids can be converted into bio-hydrogen.

Bio-reduction to produce bio fuels like bio-ethanol

The transport sector is a major energy consuming economic activity, using around 17% of the world energy consumption in 2004, equal to 78.1 EJ. Demand for mobility is worldwide increasing, it is expected that the transport sector will grow by 2.1% per year. The transport sector relies almost completely on oil as the primary energy source oil. Transport sector consumed in 2004 57.7% of total world oil production.

With the increasing energy consumption of fossil fuels, more and more CO2 is emitted in the atmosphere, a major cause of the greenhouse gas effect. The use of renewable fuels reduces the dependency on fossil fuels and decrease CO2 emissions. Political legislation and economical interest will stimulate the production of renewable fuels. An EU directive states a minimum share of renewable fuel of 5.75% in 2010 for all member states. Among renewable fuels ethanol is a viable option as it offers significant greenhouse gas benefits and it can directly be applied in present transport infrastructure. Ethanol is a fast growing market product.

The current alcohol production process are based on fermentation of sugar containing crops. Using sugars as feedstock has several disadvantages as a high feedstock price, competition with food production for arable soil and a high (fossil) energy consumption during feedstock production. In this research a new alcohol production process is proposed with digestible biomass as feedstock. Biomass mainly consists of three biopolymers lipids, proteins and carbohydrates which can be converted to short chain carboxylic acids as acetic and butyric acid during hydrolysis and acidification. Proposed alcohol production process considers a biological reduction of the liberated acetic and butyric acid. Digestion has an advantage over fermentations that is a stable process with cheap and abundant feedstock, which doesn't need a sterilisation step. Instead of converting C6 sugars to C2 alcohols, this process converts C2 fatty acid using hydrogen into C2 alcohol

Bio hydrogenation of acetate (equation 1), propionate (equation 2) and n-butyrate (equation 3) yields a small energy quantity at standard conditions (ΔG0 = -9.6, -11.5 and -5.6 kJ resp. at p0=1 atm. and pH 7). This amount of energy is in the range of what an organism should minimally catabolize to grow/ maintain cell functions. Therefore the concentrations of reactants as protons, organic acid and hydrogen are crucial to keep exothermic reaction conditions.

$$CH_3COO^- + H^+ + 2H_2 \longrightarrow CH_3CH_2OH + H_2O \qquad \Delta G_0 = -\ 9.6\ kJ\ (1)$$

$$CH_3CH_2COO^- + H^+ + 2\ H_2 \longrightarrow CH_3(CH_2)_2OH + H_2O \qquad \Delta G_0 = -\ 11.5\ kJ\ (2)$$

$$CH_3(CH_2)_2COO^- + H^+ + 2H_2 \longrightarrow CH_3(CH_2)_3OH + H_2O \qquad \Delta G_0 = -\ 5.6\ kJ\ (3)$$

Bio-oxidation to produce bio-heat

It is fashionable to burn wood to produce heat with and without electricity. This process is environmentally unfriendly. Air pollution is caused because of fine particles and acid gasses. Reuse of organics or nutrients for the soil that have grown the biomass is not possible. We propose to use bio-oxidation to produce bio-heat. In this way wood compost is produced which is a high value soil improvement fertiliser. No acid gases or fine particles are emitted and the heat recovery using a heat pump, comparable to burning.

An average Dutch household uses 1800 m3 of natural gas for heating. Bio-oxidation of wood can produce the equivalent heat of 1800 m3 natural gas using 5000 kg of low quality wood shavings.

It must be possible with the abundance of solar energy and water in all its forms to create a sustainable wealth for everyone. New technological innovations will be an important step to such a future.

Microbial Resource Management (MRM): Key strategy for environmental technology

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Summary: A variety of processes in environmental technology depend on the availability and performance of microbial resources. Engineers have difficulty to come to grips with these mixed cultures. Yet, the microbial biocatalysts behave according to straightforward thermodynamic principles. Molecular biology has brought the possibility to interpret their diversity, dynamics of evolution and functional performance. However, to become useful for practice, there is a need for ecological theory about the behaviour of microbial consortia. Moreover, feasible methods and clear default values are necessary. It is proposed that time has come for the environmental bio-technologist to apply principles of human resource management (HRM) to MRM. This way, stakeholders and providers of biotech- based environmental processes will succeed to gain in the much needed societal respectability and financial profitability.

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