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废物管理: 可持续填埋

Sino-Italian Cooperation Program
Environmental Training Community

中-意合作计划
环境培训园地

2014 Quadrimestrale Poste Italiane S.p.A. Spedizione in Abbonamento Postale – 70% DCB Venezia

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MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

Venice International University

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Editor
Ignazio Musu,
TEN Center, Venice International University

Editorial Board
Maria Lodovica Gullino,
Agroinnova, University of Turin

Edited and Published by
TEN Center, Venice International University
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Project coordination
Alessandra Fornetti, Alessandro Celestino,
Ilda Mannino, Francesca Zennaro

Graphic design
studio Cheste Venezia

Cover and On Focus photos
Andrea Penisto

English proofreading
John Francis Phillimore

Chinese translation
Mike Peng

Contributions by
Selina Angelini, Elisa Carlotto, Alessandro Celestino, Raffaello Cossu, Alessandra Fornetti, He Pinjing, Lü Fan, Ilda Mannino, Alice Ren, Ren Yanming, Shao Liming, Linda Shi, Rainer Stegmann, Denise Tonolo, Wang Shutang, Yue Dongbei, Francesca Zennaro, Zhang Hua.

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编辑
Ignazio Musu,
威尼斯国际大学-TEN中心

编委
Maria Lodovica Gullino,
都灵大学Agroinnova研究中心

编辑和出版
威尼斯国际大学-TEN中心
Isola di San Servolo
30100， 威尼斯， 意大利
意大利环境、领土与海洋部

项目负责人
Alessandra Fornetti, Alessandro Celestino,
Ilda Mannino, Francesca Zennaro

平面设计
威尼斯Cheste工作室

封面和焦点的照片
Andrea Penisto

英文校对
John Francis Phillimore

中文翻译
Mike Peng 彭迈克博士

对本书亦有贡献者
Selina Angelini, Elisa Carlotto, Alessandro Celestino, Raffaello Cossu, Alessandra Fornetti, 何品晶, 吕凡, Ilda Mannino, 任艳, 任艳明, 邵立明, 石琳, Rainer Stegmann, Denise Tonolo, 王树堂, 岳东北, Francesca Zennaro, 章骅.

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editorial
编者寄语

Nowadays the broadly agreed approach for sustainable waste management is based on the 3R's, Reducing, Reusing, Recycling. In following it, several countries are trying to phase out landfilling as the main disposal method, shifting to the new and more sustainable methods now available, such as sophisticated recycling and the reuse of waste by energy plants. However landfilling is still widely used both in developed and developing countries, not least because the transition to more sustainable methods is often long and difficult. It is therefore imperative to adopt the full range of advanced techniques when building a new landfill or managing an old one. Even if landfilling is an outdated practice, in particular for Municipal Solid Waste (MSW), it has been perfected over several decades and today can offer a high safety level against the risk of environmental pollution.
This is the reason why Sustainable Landfilling was chosen as theme of the Summer School organized in July 2014 by Venice International University and the International Waste Working Group (IWWG).
The present issue draws on the main course contents and outcomes of the Summer School and aims at offering a larger audience an overview of the topics that were discussed.
In particular, it will be explained in detail that respecting a set of minimum requirements is vital to managing a landfill in a sustainable way. The specific design and materials employed need however to be adapted to the reality of the country where the landfill is located and to the characteristics of the waste to be disposed of. Moreover, much can be learned from past mistakes in order to avoid soil and underground water pollution or the release of dangerous gases such as methane.

Francesca Zennaro,
TEN Center, Venice International University

可持续管理废物的基本思路源于3R原则，即：减量化、再利用和再循环。沿着这条思路，一些国家正逐步淘汰填埋这一废物管理主要措施，并向更新、更可持续的处理方式过渡，如：更复杂的循环处理和垃圾发电等等。然而，由于采用这些可持续处理方式需要周期更长、面临困难也更多，目前填埋仍然是发达和发展中国家所采用的主要处理处置手段。因此在建立新填埋场、或者管理旧填埋场时，应尽可能采用最先进技术。尽管垃圾填埋、特别是城市生活垃圾填埋技术由来已久，但在过去几十年已得到逐步完善，现如今填埋技术已达到较高环境安全水平。
为此，威尼斯国际大学和国际废物工作组(IWWG)于2014年7月合作举办了可持续填埋暑期培训班。
本期通讯集中刊载暑期培训班的主要成果及内容，旨在让更广大群体能够从中受益。
本期通讯将详细介绍以可持续方式管理填埋场的最低要求。当然，由于各填埋场所处位置不同，处置垃圾的特点也各异，因此需根据具体实际情况进行有针对性设计，并选用不同建筑材料等。此外，可大量借鉴过去的经验教训，以避免对土壤和地下水产生污染，并释放甲烷等有毒气体。

Francesca Zennaro,
威尼斯国际大学-TEN中心

Costs of air pollution from European industrial facilities 2008-2012

The European Environment Agency (EEA) recently released its *"Costs of air pollution from European industrial facilities – an updated assessment"* report, which evaluates a number of harmful impacts caused by air pollution on the health of the European population.
This report follows the one published in 2011 and analyses the emissions coming from industrial facilities included in the European Pollutant Release and Transfer Register (E-PRTR) in the period between 2008 and 2012.
To evaluate the extent of the damage (which includes premature death, hospital costs, lost work days, health problems, damage to buildings and reduced agricultural yields), the EEA used a range of cost estimates, as there are several different existing methods currently used by policy-makers to calculate collateral damage costs. The results show that air pollution and greenhouse gases from industry cost Europe between € 59 and € 189 billion in 2012. Over the period 2008 - 2012 the estimated cost was at least € 329 billion and possibly up to € 1,053 billion.
The report also lists the 30 most polluting facilities, mainly coal fired power plants located in Germany and Eastern Europe and highlights that 50% of the total damage cost occurs as a result of emissions from just 1% of the 14,325 facilities assessed in the study.
The research also tries to account for the efficiency of the facilities assessed. Since fuel consumption or production output data are not available in the E-PRTR register, the report used the estimated damage costs by CO_2 emissions as a rule-of-thumb proxy for fuel consumption.
The result show more facilities from Eastern Europe appearing at the top of

2008-2012年期间欧盟工业设施产生空气污染所导致的损失

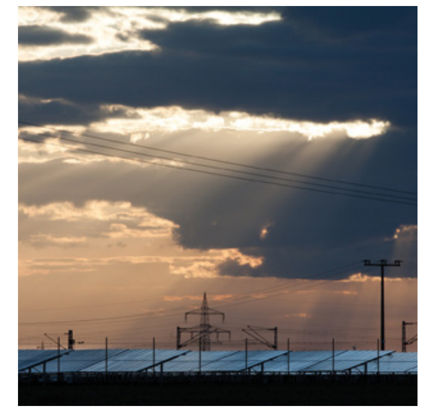
欧盟环境署最近发布了《欧盟工业设施产生空气污染所导致的损失——更新评估报告》，对空气污染给欧盟居民健康所造成的有害影响进行了评估。在2011年报告基础上，本次评估对“欧盟污染物排放和转移登记制度”(E-PRTR)管理下的所有工业设施在2008-2012年期间所排放的污染物进行了全面分析和评估。

为了评估所造成的损失（包括过早死亡、医疗费用、因病不能上班、健康问题、对建筑造成的损失、农业减产等等），欧盟环境署利用政策制定者常用的估算损失方法进行了一系列测算。测算结果表明：2012年空气污染和温室气体排放所造成的经济损失至少有590亿和1890亿欧元。2008-2012年期间总损失为3290亿欧元，甚至高达10530亿欧元。

the results, suggesting that they are less environmentally efficient and relatively more damaging to health and the environment. The same happens when the costs to environment and health are adjusted to reflect the national GDP. Emissions from a number of Eastern European countries (Bulgaria, Romania, Estonia and Poland) emerge as the most significant.
The aim of the report is not to provide a comprehensive view on air pollution in Europe, and it recognizes that other sectors, primarily transport and agriculture, also contribute to poor air quality. However it is important to raise awareness about the hidden costs to our health and the environment coming from industry and power generation, even if significant economic and social benefits (such as the products themselves, employment and tax revenues) are generated from these sectors.
The report is available for download on the EEA website:
http://www.eea.europa.eu/publications/costs-of-air-pollution-2008-2012

IPCC publishes the Synthesis Report of the Fifth Assessment Report (AR5) on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) met in Copenhagen at the end of October to finalize the Synthesis Report, the last stage of its Fifth Assessment Report (AR5), which provides policymakers with a comprehensive assessment of the risks of climate change. Their work, released on November 2, completes the Fifth Assessment Report, the most comprehensive assessment of climate change yet undertaken. The first three volumes were released over the preceding fourteen months: The Physical Science Basis in September 2013, Impacts, Adaptation and



报告还列举了污染最重的30个工业设施，主要包括德国和东欧的燃煤发电厂，并指出造成50%经济损失的工业设施占被评估的14,325个工业设施的1%。
该报告还对设施效率所带来的损失进行评估。但由于“欧盟污染物排放和转移登记制度”下没有能源消耗和工业产值方面的数据，报告用二氧化碳排放量作为能源消耗指标对所造成的损失进行统一估算。分析结果表明：东欧国家的工业设施排名最靠前，即：这些国家的工业设施环境效率更低、对人体健康和环境造成的危害更大。把对环境和人体健康所造成的影响与国民生产总值进行相关联，所得到的结果也是一致的。东欧国家（保加利亚、罗马尼亚、爱沙尼亚和波兰）的排放量最高。
该报告不仅提供了欧盟空气污染的总体情况，而且还指出交通和农业等其他行业也是造成空气质量下降

Vulnerability, in March 2014 and Mitigation of Climate Change in April 2014.
The Synthesis Report confirms that climate change is being registered around the world and that warming of the climate system is now indisputable. Recent assessments find that the concentration of carbon dioxide has increased to a level unprecedented in at least the last 800,000 years. If no action is taken, the impact on people and ecosystems will be widespread and irreversible. However, the implementation of stringent mitigation measures can ensure that the impacts of climate change remain within a manageable range, while some options are available to adapt to the effects of climate change.
The report expresses with greater certainty than in previous assessments the fact that emissions of greenhouse gases and other anthropogenic drivers have been the dominant cause of observed warming since the mid-20th century. It also highlights the fact that the least developed countries and vulnerable communities will be the most challenged, given their limited ability to cope. On the other hand, many of those most vulnerable to climate change have contributed and continue to contribute little to greenhouse gas emissions. International cooperation will therefore be needed to achieve sustainable development together in an equitable and just manner.
Adaptation can play a key role in decreasing climate change risks but that alone is not enough. Substantial and sustained reductions of greenhouse gas emissions are also needed, both to reduce the magnitude of global warming and to gain more time for adaptation.
The report finds that a transition to a low-carbon economy is technically feasible and need not seriously compromise global economic growth. However, specifically targeted policies are lacking. It also stresses the fact that the delay in taking action will significantly increase the costs of both adaptation and mitigation.
As Rajendra K. Pachauri, Chair of the IPCC, said in his address, little time is left before the window of opportunity for staying within 2°C of warming closes. To keep a good chance of staying below 2°C, and at manageable costs, emissions should drop by 40 to 70 percent globally between 2010 and 2050, falling to zero or below by 2100.

的重要行业。尽管一些行业所产生的经济和社会效益比较可观，但应对其所造成的健康和环境隐性损失给予高度重视。
在欧盟环境署的网站上可以下载该报告：
http://www.eea.europa.eu/publications/costs-of-air-pollution-2008-2012

政府间气候变化专门委员会公布第五次气候变化综合评估报告

政府间气候变化专门委员会（IPCC）于10月底召开会议，最终审议通过了第五次评估报告(AR5)，报告对气候变化所面临风险进行了综合评估，并提出相关政策框架。
报告于11月2日发布，是截止目前针对气候变化所进行的最全面评估。前三卷在此前14个月期间陆续发布：2013年9月发布《物理科学基础》，2014年3月发布《影响、适应性与脆弱性》，2014年4月发布《气候变化减缓》。
《综合报告》确认世界各地都在发生气候变化，而气候系统变暖是毋庸置疑的。评估发现自20世纪50年代以来，二氧化碳浓度的变化幅度在过去80万年里是前所未有的。如果不采取行动，将对人类和生态系统产生广泛的、不可逆转的影响。
如果能够采取严格削减措施，则可将气候变化带来的影响控制在可控

范围，同时还可采取些措施来适应气候变化带来的影响。
相比之前的评估报告，本报告更为肯定地指出一项事实，即温室气体排放以及其他人为驱动因子已成为自20世纪中期以来气候变暖的主要原因。《综合报告》明确证实，鉴于最不发达国家和脆弱群体的应对能力有限，其所面临的挑战也最为严峻。而许多脆弱国家对温室气体排放的贡献历来很小、今后也不大。因此，需要加强国际合作，以公平、公正的方式来推动实现可持续发展。
但仅靠适应是不够的。大幅和持续减少温室气体排放是降低全球变暖幅度和赢得时间适应变化的核心。
报告认为向低碳经济转型从技术上是可行的，而且也不会对全球经济增长带来严重影响，但缺乏有针对性的政策。报告指出推迟采取行动将会造成适应和削减成本大幅提高的后果。
IPCC主席帕乔里在讲话中指出，将气候变暖温度控制在2度以内，给我们留下的时间不多了。如果想将上升温度控制在2度以下，并且减排措施控制在可承受成本范围内，那么在2010—2050年期间应将温室气体削减40-70%，到2100年削减到零排放。
该报告可在IPPC 网站下载：
http://www.ipcc.ch/report/ar5/syr/

意大利资源循环利用行业——2014年报告

近日可持续发展基金（Fondazione per lo Sviluppo Sostenibile）和意大利废物收集与循环利用行业协会（FISE Unire）联合发布了《意大利循环利用行业报告》，报告集中介绍了意大利资源循环利用市场等方面的内容。
报告结论喜人：尽管生产行业正经

The report is available for download on the IPPC website
http://www.ipcc.ch/report/ar5/syr/

Recycling in Italy – 2014 report

The report “L’Italia del Riciclo”, focusing on the state of the recycling market in Italy, was recently published by the Fondazione per lo Sviluppo Sostenibile (the Sustainable Development Foundation) and by FISE Unire (the Italian association of companies working in the waste collection and recycling sectors).
The report presents an encouraging situation, in which the Italian waste management sector is steadily growing notwithstanding a generalized condition of crisis of the productive sector. In the last 5 years the number of workers in the sector increased by 13% and the number of companies (94% of which are in the collection division) increased by 10%. Their total turnover amounted to 34 billion Euros.
The 1% increase in packaging recycling in the period 2011-2013 is particularly significant because in the same interval both industrial production and consumption shrank. The most successful sectors were paper (86%), steel (74%) and glass (65%), while other productive chains (e-waste, building waste, textiles) still do not reach either national or European targets.
The report underlines that there are wide margins for improvement for the waste sector, both at national and European level. Stronger initiatives for waste prevention, ecodesign and re-use could bring up to 600 billion a year in savings and create 600,000 jobs, while making the European market more competitive and reducing the need for raw materials.
At the same time it is recognized that more can be done at the political and administrative level in order to offer companies clearer rules and easier procedures and to shift from the “waste” to the “secondary raw material” concept.
The efficient use of resources (including waste) is in fact one of the main pillars for the development of a green economy and for a more sustainable growth.
The report is available for download at this link (Italian only):
http://www.fondazionesvilupposostenibile.org/dtl-1648-Report%3A_L_Italia_del_riciclo_2014_?cid=1227274

历寒冬，但意大利废物管理行业却企稳增长。在过去15年该行业从业人员增长了13%，企业数量（其中94%为废物收集企业）增长了10%。生产总值达到340亿欧元。
2011-2013年期间包装材料回收行业增长率高达1%，而同期无论是工业生产还是消费行业都在萎缩下降。对纸张(86%)、钢铁(74%)及玻璃(65%)等的回收利用最为成功，而其他生产行业（电子垃圾、无机物、纺织品）的废物回收利用尚未达到国家及欧盟目标。
报告认为在国家和欧盟层面，废物回收利用行业都有很大改进空间。通过采取强有力措施避免废物产生、加强生态设计、提高再利用率等，可以每年直接产生6000亿欧元产值，创造60万个就业机会；同时还可以增强欧盟市场竞争力，减少对原材料的消耗。
报告还认为应该在政策和管理层面进行改革，向企业明确管理要求，简化审批程序，并彻底改变观念，即：没有废物而只有二次原材料的概念。事实上，资源有效利用（包括废物）是发展绿色经济、实现可持续增长的重要支柱。
在以下网址可下载该报告（意大利文）：
http://www.fondazionesvilupposostenibile.org/dtl-1648-Report%3A_L_Italia_del_riciclo_2014_?cid=1227274

北京批准2020年气候变化目标

中国中央政府批准了2020年实现气候变化目标的国家计划。
中国国务院批准了国家发展和改革委员会提出的这项计划。国家发展和改革委员会负责中国的经济规划。中国已经承诺到2020年单位国内生产总值的碳排放强度减少到2005年水平的40%~45%。中国届时还要实现非化石能源占初级能源总

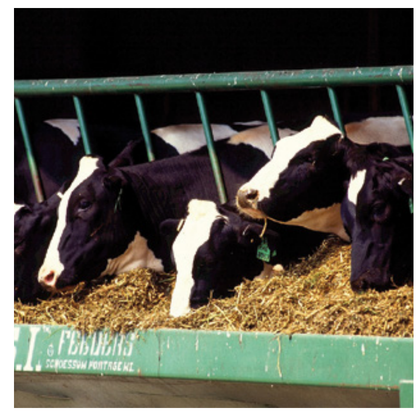
Beijing approves 2020 climate goals

The Chinese central government has approved a plan that maps out major climate change goals to be met by 2020.
The State Council, China's cabinet, has given a green light to the plan, which was proposed by the National Development and Reform Commission (NDRC), the country's economic planner. China has pledged to reduce its carbon emission intensity, that is to say emissions per unit of GDP, by 40%-45% by 2020 from the 2005 level. It will also aim to bring the proportion of non-fossil fuels up to about 15% of its total primary energy consumption. Other targets include increasing forest coverage by 40 million hectares within the next five years.
The government will speed up efforts to establish a carbon emission permit market, under the plan, which also calls for deepened international cooperation under the stated principles of 'common but differentiated responsibilities', equity and respective capability.
The State Council said local governments and departments at all levels should recognize the significance and urgency of dealing with climate change and give higher priority to action on this issue.
Xie Zhenhua, deputy chief of the NDRC and the country's top official on climate change, told a press conference that the plan demonstrated concrete action by China towards playing its part in the global process of tackling climate change.
Source:Xinhua

2014 Annual General Meeting of China Council for International Cooperation on Environment and Development opens in Beijing

The 2014 Annual General Meeting of the China Council for International Cooperation on Environment and Development (CCICED) was opened in Beijing on December 1, 2014. The theme of this Annual General Meeting was "Management and Institutional Innovation in Green Development". Mr. Zhang Gaoli, Member of the Standing Committee of the CCCPC Political Bureau, Vice Premier of the State Council and CCICED Chairman attended the opening ceremony and delivered a keynote speech.
At the meeting, the Minister of Environmental Protection Zhou

消费量大约15%的目标。其他目标包括未来五年内植树造林达4000万公顷。
根据这项计划，中国政府将加快建立碳排放交易市场。中国呼吁根据“共同但有区别的责任原则”、公平原则和基于各自能力的原则，加强国际合作。
国务院表示，各级地方政府和部门应该认识到应对气候变化的重要性和紧迫性，并针对这个问题采取优先行动。
国家发展和改革委员会副主任解振华是中国应对气候变化的最高官员，他在新闻发布会上说，这项计划是中国加入全球应对气候变化所采取的具体行动。
来源：新华社



中国环境与发展国际合作委员会2014年年会在京顺利开幕

中国环境与发展国际合作委员会（简称国合会）2014年年会于12月1日在北京开幕。年会以“绿色发展的管理制度创新”为主题。中共中央政治局常委、国务院副总理、国合会主席张高丽出席开幕式并作主旨发言。
大会上，周生贤部长做了题为“主动适应新常态，构建生态文明建设和环境保护的四梁八柱”的特别演讲，其中简要介绍了刚刚召开的中国共

Shengxian gave a special speech with the title "Adapting to the 'new normal' and developing the framework for the development of ecological civilization and environmental protection". In his speech, he gave his listeners a brief introduction to the important measures identified by the Fourth Plenary Session of the 18th National Congress of the Chinese Communist Party, which involved employing the legal system to protect ecological environment, and to significant progress in the development of an ecological culture promoted by the CCCPC and the State Council. The main matter of his speech introduced the Chinese and international Members to important measures taken to ensure that the development of an ecological culture and the master plan for environmental protection adapt to the 'new normal' of the Chinese economy. Developing the framework for an ecological culture and environmental protection, he said, lays the groundwork for a macro and systematic structure of the development of that ecological culture and for environmental protection. This is the result of the coordinated response of environmental protection institutions to, and their in-depth implementation of, important speeches of General Secretary Xi Jinping; a crystallization of the practice and developing understanding of our country in the protection of ecological environment over the past few years as well as the innovative thinking of the MEP in overall promotion and achieving breakthrough in key areas. Mr. Achim Stainer, Vice General Secretary of the United Nations, Executive Director of UNEP and CCICED Vice Chairman and Mr. Xie Zhenhua, Vice Minister of NDRC and CCICED Vice Chairman also addressed the meeting.
This AGM had two forums, the theme of one being 'Institutional Innovation for an Ecological Culture' and of the other "Green Transformation and the Outlook for China". They provided Chinese and International Members and Task Forces with an opportunity for face-to-face exchanges and the sharing of international successful experiences in environment and development, and amply demonstrated the openness and inclusiveness of the CCICED as an international think tank and

exchange platform. During the meeting, experts and Members discussed a series of study reports and policy recommendations including "Assessment and Outlook for Green Transformation Processes in China", "Innovations in the Environmental Protection System within the Development of an Ecological Culture", "Urbanization Modes and Systems Based on the Concept of Ecological Civilization", "Institutional Innovation for a Red Line in Ecological Conservation", "Performance Assessment and Regional Coordination Mechanisms for the Action Plan for Prevention and Control of Air Pollution" and "The Government Environmental Audit System". In conclusion the meeting developed a series of Policy Recommendations to the Chinese Government.
Source: www.cciced.net

China and the United States release joint announcement on climate change

China and the United States released the U.S.-China Joint Announcement on Climate Change in Beijing on November 12, 2014. The Announcement emphasised that the United States of America and the People's Republic of China have a critical role to play in combating global climate change, one of the greatest threats currently facing humanity. The two sides will strengthen bilateral cooperation on climate change and will work together with other countries to adopt a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties at the United Nations Climate Conference in Paris in 2015.
The Presidents of the United States and China announced their respective post-2020 programs for action on climate

产党十八届四中全会所提出的利用法律制度来保护生态环境的重要举措以及党中央国务院推进生态文明建设所取得的重大进展，重点就当今生态文明建设和环境保护的总体规划如何适应中国经济新常态的重要举措向参会的中外委员和参会嘉宾做了介绍。他说，构建生态文明建设和环境保护的四梁八柱，形象勾勒了生态文明建设和环境保护的宏观性、系统性的整体架构，是环保部门深入贯彻落实习近平总书记系列重要讲话精神的集中体现，是一段时期以来我国生态环境保护探索实践的认识升华，是坚持整体推进、重点突破工作思路的创新举措。联合国副秘书长、环境署执行主任、国合会副主席施泰纳，国家发展和改革委员会副主任、国合会副主席解振华向大会发表致辞。
本次年会还将设立两个平行论坛，主题分别是"生态文明的制度创新"和"中国绿色转型与展望"，为出席会议的中外委员和代表以及政策研究组提供面对面交流和分享国际社会环境与发展成功经验的机会，充分体现了国合会作为国际智库和交流平台的开放性和包容性。
年会期间，与会专家、委员还将就一系列研究报告与政策建议进行讨论，包括"中国绿色转型进程评估与展望"，"生态文明建设背景下的环境保护制度体系创新"，"基于生态文明理念的城镇化发展模式与制度"，"生态保护红线制度创新"，"大气污染防治行动计划绩效评估与区域协调机制"和 "政府环境审计制度"等，并最终形成给中国政府的政策建议。
来源： www.cciced.net

中美发表气候变化联合声明

11月12日，中美双方在北京发表《中美气候变化联合声明》。该声明指

出，中美两国在应对全球气候变化这一人类面临的最大威胁上具有重要作用，双方将携手与其他国家共同努力，力争促成在2015年联合国巴黎气候大会上达成具有法律效力的议定成果。
中美两国元首宣布了各自"后2020年应对气候变化行动目标"：美国计划于2025年实现在2005年基础上减排26%-28%，并将竭尽全力争取实现减排28%。中方计划在2030年二氧化碳排放达到峰值，并将努力实现早日达峰；计划到2030年非化石能源占一次能源消费比例提高到20%左右。中美两国希望，上述目标能够为全球气候谈判注入动力，并带动其他国家共同尽快并尽可能在2015年第一季度提出有力度的行动目标。 两国元首决定紧密合作，克服妨碍巴黎会议达成全球气候协议的所有主要障碍。
技术创新，包括新的零碳和低碳技术发明和推广，对于降低当前减排成本至关重要，并可以极大增强各国减排能力。中国和美国是世界上两个最大的清洁能源投资国，并已建立了成熟的能源技术合作计划。为进一步支持落实两国气候目标，双方还宣布了通过现有途径特别是中美气候变化工作组、中美清洁能源研究中心和中美战略与经济对话等平台进一步加强和扩大两国合作。这些措施包括扩大清洁能源联合研发，推进碳捕集、利用和封存重大示范，加强关于氢氟碳化物的合作，启动气候智慧型/低碳城市倡议，推进绿色产品贸易，实地示范清洁能源，在建筑能效、锅炉效率、太阳能和智能电网方面开展更多试验活动、可行性研究和其他合作项目。
来源： http://news.xinhuanet.com/politics/2014-11/17/c_127218099.htm

change. The United States intends to achieve an economy-wide target of reducing its emissions by 26%-28% below their 2005 level by 2025 and to make best efforts towards hitting the higher target of 28%. China intends to achieve a peaking of CO_2 emissions around 2030 and to make best efforts to peak earlier, and also intends to increase the share of non-fossil fuels in primary energy consumption to around 20% by 2030. The United States and China hope that by announcing these targets now, they can inject some momentum into the global climate negotiations and inspire other countries to join them in coming forward with ambitious programs as soon as possible, preferably by the first quarter of 2015. The two Presidents resolved to work closely together over the next year to address major impediments to reaching a successful global climate agreement in Paris.
Technological innovation is essential for reducing the cost of current mitigation technologies, encouraging the invention and dissemination of new zero and low-carbon technologies and enhancing countries' capacity for reducing their emissions. China and the United States are two of the world's largest investors in clean energy and already have a robust program of energy technology cooperation. In order to support the achievement of the climate targets of the two countries, the two sides have announced that they will strengthen and expand bilateral cooperation, using the existing vehicles, in particular the U.S.-China Climate Change Working Group (CCWG), the U.S.-China Clean Energy Research Center and the U.S.-China Strategic and Economic Dialogue. These measures include expanding joint research projects for the development of clean energy, advancing major carbon capture, utilization and storage implementation, enhancing cooperation on HFCs, launching a climate-smart/low-carbon cities initiative, promoting trade in green goods, introducing clean energy on the ground and carrying out additional pilot programs, feasibility studies and other collaborative projects in the areas of building efficiency, boiler efficiency, solar energy and smart grids.
Source: http://news.xinhuanet.com/politics/2014-11/17/c_127218099.htm

Technical Evolution and the Role of Landfilling in Modern Waste Management Strategies: from Open Dump to Geological Repository

现代废物管理战略与填埋技术演进及其作用: 从开放式倾倒到地质贮藏

Raffaello Cossu,
DII – Department of Industrial Engineering, University of Padua
帕多瓦大学工业工程系
raffaello.cossu@unipd.it

Introduction

The passage from a linear to a circular approach has characterised waste management (WM) strategies in the last decade, moving from triangles (Integrated Hierarchy) to circles (Cossu, 2009). More and more waste is considered a resource to be reused, to be recycled, either as material or energy. But after the various cycles of reuse and recycling there will always be some residual material that will need to find a final sink. From this point of view the depositing of waste matter on the ground is an undeniable reality, an inescapable aspect of closing the material cycle (Cossu, 2009). Failure to acknowledge this would be tantamount to denying Lavoisier's Principle of Mass Conservation (Cossu, 2012). There are a number of ways that waste is deposited on the ground, ranging from the uncontrolled or scarcely controlled landfilling of untreated wastes (such as occurs in some developing countries) to sanitary landfilling in countries with a wide availability of land, from landfills for mechanically, biologically or thermally pretreated wastes to the use of compost in agriculture and the recycling of waste residues in building materials (bricks, concrete, asphalts, aggregates for road construction, etc.) which ultimately also serve as a sort of landfill. Under normal conditions, if no significant pretreatment has been applied, materials after deposition as waste undergo several physical, biological and chemical reactions. As a consequence landfills can be considered as reactors in which liquid, solid and gaseous materials interact giving rise to liquid (leachate) and gas (biogas) emissions together with a solid residue (the landfilled waste) representing a source of potential further emissions. Gas and leachate emissions contain substances capable of contaminating the environment. Favourable natural phenomena or active measures adopted to attenuate or prevent the uncontrolled diffusion of emissions and consequent onset of environmental and health risks are classified as barriers. The manner in which these barriers are conceived has marked the technical development of landfills (Figure 1), following cultural developments in modern society, and reflecting a growing social and political awareness of environmental issues.

Technical evolution

Not so long ago uncontrolled dumping was the main

引言

过去几十年废物管理理念走过了从线性到圆圈的历程，从三角形(综合层级)向圆形演进 (Cossu, 2009)。越来越的废物被当作资源或能源被再次利用。但经过再利用、循环使用后，仍会产生剩余物质需要最终进行填埋。

从这个角度来看，将废物最终进行填埋是不可避免的环节，也只有这样才能完成物质循环链 (Cossu, 2009)。 不承认这一点就是对拉瓦锡物质守恒定理的否定(Cossu, 2012)。 废物填埋方式多种多样，有些国家对废物不进行任何处理，完全是一种无控制式填埋或采取稍许控制措施进行填埋（很多发展中国家都存在这种情况）；而有些国家则会采取卫生填埋的方式，对废物进行机械、生物或热预处理，或者进行农业堆肥，对建筑垃圾加大废物循环利用（砖、混凝土、沥青等用来修路），当然对于最终产生的、不可再利用的废物，还得进行填埋处置。

一般情况下，如果对废物没有进行比较严格处理，那么进入填埋场的废物则会发生物理、生物和化学反应。填埋场竟然变成了反应池，液体、固体和气体物质在里面相互作用，并进而产生新的液体（渗滤液）、气体（沼气）和固相物质（填埋废物）。沼气和渗滤液会造成新的环境污染。

通过有利的自然现象或积极主动采取措施，可以减缓或预防污染物排放对人体健康和环境带来风险。这些措施标志着填埋场技术进步的历程（图1），顺应了现代社会文化的发展，并反映出普通公众和政治家环境意识得到不断提高。

技术演进

不久前，世界各国基本仍都采用无控制倾倒废物处理方式。现阶段世界人口一半以上仍采用这种废物处理方式。这种方式没有建造任何现代基础

Fig. 1: Chronological development of concepts, technologies and management procedures for waste landfilling
图1: 工业化国家废物填埋理念、技术和管理所走过的历程

< 1960	**Uncontrolled Dumping** **无控制倾倒**	No infrastructures / 无基础设施 No environmental control / 无环境控制 Random combustions / 随意焚烧 Scavengers / 食腐动物
1960-1980	**Controlled tipping** **控制式倾倒**	'Attenuate and disperse' approach / 衰减和分散原则 Daily covers / 每日覆盖 Thin waste layer deposition / 薄层废物贮存 Fencing and scavenging control / 围栏和食腐动物控制措施
1980-2000	**Contained landfilling** **采取防护措施式填埋**	Lining systems (clay, HDPE) / 铺设衬层（泥土层、HDPE） Leachate and biogas management / 渗滤液和沼气管理 Waste compaction / 废物压实 Low permeability surface capping / 低渗透性覆顶封闭
2000-2010	**Residual waste landfilling** **剩余废物填埋**	Multibarrier approach / 多种屏障原则 Waste pretreatment / 废物预处理 Environmental monitoring / 环境监测 Post-closure financial provision / 封闭后管理资金保障
> 2010	**Sustainable landfilling** **可持续填埋**	Environmental sustainability measures / 可持续环境措施 No or fully mineralised degradable organics / 无或全部矿化可降解有机物 Long-term impact control / 控制长期影响 Carbon sink and immobilisation of metals / 碳沉降和金属固化

设施，也没有采取任何环境控制措施；在倾倒现场，经常会出现大量食腐动物和捡垃圾人，这些人依靠挑拣垃圾为生（图1）。
自上个世纪六十年代以来，在一些工业化国家，无控制废物倾倒逐步被控制型倾倒所取代，并根据世界卫生组织制定的系列标准进行了规范。随着时间推移，这些标准后来逐步成为该行业主要技术参考资料。垃圾填埋场废物下面的衬层（人工或天然）具有不饱和低渗透性，但随着时间推移其隔离性会逐步衰减。根据“衰减和分散”原则，要求对上述填埋场渗滤液进行监测。为此，填埋场一般不应该建在高渗透性土壤上，也不应选址在潜在生态脆弱区域。将废物分层铺放并压实，以改善其好氧条件，然后覆盖一层惰性材料（最好是泥土），以避免动物（狗、鸟、啮齿类、昆虫等）等有机会接触到废物。
按照规定垃圾填埋场周围必须建设隔离墙，但并未规定对渗滤液和沼气进行收集。允许渗滤液渗入土地；从好氧条件角度考虑，对沼气排放也未作任何要求。由于对不饱和区域和废物层之间空气流动情况未给予应有关注，没有要求进行任何实际监测。然而现实情况与规划情景并不完全一致，最终这类填埋场往往出现有毒气体、渗滤液等排放的情况，在填埋场周围形成令人作呕的水坑。
上述情况屡屡发生，公众意识不断提高，伴随着该领域科学技术不断进步，在上个世纪八十年代，出现了“控制性填埋”，其特征是采取措施控制污染物排放、铺设人工防渗系统、安装渗滤液排水和收集系统、废物压实处理、进行厌氧反应、沼气回收利用、对填埋场最终加盖覆顶处理。在防渗方面，除了用泥土层外，还广泛使用合成膜，早期使用PVC，后来更多使用高密度聚乙烯(HDPE)。
需要采用相关技术对所收集的渗滤液和沼气进行处理处置。最初对沼气的处理是点火炬烧掉，后来又出现了一些回收技术，包括沼气热电回收、沼气民用、机动车燃料等；同时还要求采取相应措施对渗滤液进行处理。但由于渗滤液产生速度变化无常，并含有大量有机物和氨，而且随着填埋场老化，渗滤液的质量变化程度很大，因此渗滤液被称为是最难处理的一种废水。1980s以来人们更多采取的是氧化塘处理方式，即采用生物处理、反渗透池、活性炭吸附、化学沉淀与氧化、蒸发、植物吸附等技术(Christensen, Cossu, Stegmann, 1993)。

approach employed for the final disposal of waste worldwide, and it is a system still applied today as the main means of waste disposal by more than half the world population. This form of waste disposal is not supported by any form of modern infrastructure or environmental control and is invariably associated with the presence of scavengers, people who make their living from recovering marketable scrap from the deposited wastes (Fig. 1).
In the 1960s the use of uncontrolled dumping was gradually replaced in several industrialized countries by controlled tipping, encoded by the World Health Organisation in a series of guidelines which have evolved over a considerable period of time into the main technical reference point in the field.
In accordance with the 'dilute and disperse' principle the above type of landfill provided for leachate monitoring based on attenuation throughout the unsaturated low permeability ground layers (either natural or artificial) underlying the waste. Accordingly, landfills were not sited on land characterized by highly permeable soils or at potentially vulnerable sites. Waste was deposited in thin uncompacted layers with a view to enhancing the establishment of aerobic conditions and was covered with inert material (preferably clay) to prevent contact between the waste and animals (dogs, birds, rodents, insects, etc). Provision was made for the fencing off of landfill areas. Collection of leachate and biogas was not provided for; leachate was allowed to infiltrate into the ground, whilst biogas production was not contemplated due to the creation of aerobic conditions which were meant (optimistically) to prevent this phenomenon.
In the majority of cases things did not go exactly as planned, particularly because little attention was paid to monitoring the unsaturated area and air circulation between the waste layers was extremely limited. Therefore, this type of landfill frequently resulted in noxious odours, leachate emissions from the accumulation of leachate inside the landfill or in nauseating puddles around the landfill.
The repeated occurrence of similar situations and an increased public awareness of environmental issues, together with technical and scientific progress in the field, has led since the 1980s to the increasing use of 'Contained landfill', featuring controlled emissions, artificial lining systems, leachate drainage and collection, waste deposition by heavy compacting, anaerobic processes, biogas collection and final capping. In addition to clay as a liner, the use of synthetic membranes, initially PVC and then high density polyethylene (HDPE), became increasingly popular.
The controlled, collected emissions were naturally subjected to subsequent treatment and disposal, necessitating specific technologies. Biogas was initially flared, although subsequently numerous recovery techniques have been applied ranging from the production of thermal and electric power to upgrading of gas for domestic use and use as vehicle fuel. Increasingly

由于渗滤液处理成本较高，因此尽量减少渗滤液产生成为趋势。为此需给填埋场覆盖不透水层，以尽可能避免雨水流入废物填埋场。这种管理措施解决了一方面问题，但与此同时却引发新的问题，即：由于填埋坑内缺水，造成迟滞（并最终抑制）废物生物降解过程。这导致废物干化，进一步延长了填埋场所造成的长期有害影响。

随着时间推移，人们认识到控制式填埋场存在很多局限性。特别是对高强度新材料的“盲目”采用，导致对这些材料过度依赖（例如，多层铺设合成膜，而没有考虑将这些防渗膜与地质层结合），同时也造成一些填埋场建在脆弱区域内。尽管最小村庄最不精明的村长都绝对不会同意在这样的区域建造这类垃圾填埋场，但填埋场往往会获得批准并修建在砾石坑、有泉水的山谷、有渗水的采石场等等。

由于存在大量使用长效材料、机械运转不可靠、失当管理和表面化设计思想等问题，与开放式废物倾倒或简单填埋处理相比，这种填埋场比所造成的环境影响更加恶劣。现如今当人们讨论对填埋场进行改造时，往往会发现需要采取大量措施进行改造的、更多的是过去30年间所建造的填埋场。这种例子在意大利很多 (例如 Vallin dell'Aquila, La Spezia; Fossano, Cuneo等等)。

“剩余废物填埋”是对废物进行分级管理的模式，并很快在全世界范围内被广泛接受(Cossu, 2009)。在采取措施进行预防废物产生、材料再利用、能源回收后，最终剩下的物质被称为剩余废物(飞灰、不可循环利用材料、杂质等等)。尽管现如今填埋场仍然具备控制式填埋场特点，但所填埋的废物基本上都是剩余废物。剩余废物填埋的终极目标是减少填埋量、减少温室气体产生，并降低环境影响和风险。此外，大多数工业化国家要求填埋场运营方必须安排适当资金，对封闭后填埋场仍进行监测。只要填埋场对环境持续造成风险，运营方就有义务进行长期后续监测。

然而，控制式剩余物填埋模式仍然不能满足现代环境可持续管理要求，即：不能将不可接受的环境负担留给子孙后代。

尽管关于对填埋场进行长期管理的政策框架（封闭后监测管理、填埋场运营者长期责任）已经被广泛采纳，但尚缺乏具体实施办法和工具。事实上，目前所采取的措施是基于时间而非环境影响来进行填

complex treatment technologies have also been applied to leachate, one of the most difficult wastewaters to treat due to the inconsistency of its rate of production, high organic and ammonia content and the wide quality variation linked to landfill ageing. The simple system of aerated lagoons of the 1980s gave way to treatment options calling for high technologies involving biological treatment, reverse osmosis, activated carbon absorption, chemical precipitation and oxidation, evaporation, phyto-reduction, etc. (Christensen, Cossu, Stegmann, 1993).

The high management costs associated with leachate treatment have resulted in a tendency to minimize, if not to totally prevent, leachate production, by inhibiting the inflow of rainwater to the waste body by means of an impervious surface capping of the landfill. On the one hand this strategy may solve a management issue, but on the other it can incubate an environmental problem in view of the fact that the lack of water slows down (and even totally inhibits) biological waste degradation. This may result in a sort of waste mummification and a prolonged potential for the long-term deleterious impact of landfills.

Over the years the 'Contained landfill' approach has displayed numerous limitations. In particular, the 'blind' acceptance of the potential efficiency of new materials has led on the one hand to an excessive reliance on their use (e.g. use of multiple synthetic layers without coupling them with mineral liners), and on the other to the development of landfills on vulnerable sites on which even the least astute mayor of the smallest village would never previously have thought of siting a dump or a simple landfill. Landfills have consequently been licensed in gravel pits, in valleys with springs, and in quarries with water seepage, etc.

The limited long-term efficacy of materials and technologies, mechanical fallibility, inappropriate management and superficial design approaches have at times resulted in more severe environmental impacts than ever occurred with open dumps or old simple landfills. Thus when discussing the reclamation of old landfills one may find oneself overstating their defects, given that major reclamation interventions quite often prove necessary on the 'modern' contained landfills built over the last thirty years. Several examples of this can be found in Italy (e.g. Vallin dell'Aquila, La Spezia; Fossano, Cuneo, etc.)

The 'Residual waste landfill' was first developed in the context of a hierarchical view of waste management and rapidly became an international reference strategy (Cossu, 2009). Subsequent to the various stages of Waste Prevention, Material Re-use and Recycling, and Energy Recovery, residual wastes (ashes, non-recyclables, impurities, etc.) are formed. Although today's landfills continue to display the characteristics established for a contained landfill, they now predominatively constitute a deposit for residual wastes. The ultimate objective of a residual landfill is to reduce the volume of waste deposited, to minimize the production of greenhouse gases and generally to lower environmental impacts

and risks. Moreover, the majority of industrialized countries have introduced criteria for the monitoring of landfills during the post-closure stage, insisting that landfill operators make financial provision and take responsibility for overseeing sites for as long as landfills continue to constitute a risk for the environment.

However, the evolution of 'contained' into 'residual' landfills has not developed at the same pace as modern environmental sustainability requirements which preclude leaving future generations to manage unacceptable environmental burdens.

Unfortunately, although a regulatory framework has been widely adopted outlining measures for controlling long-term impact (post-closure care, long-term operator environmental responsibility), the appropriate tools for its implementation are still lacking. Indeed, termination of post-closure care is currently calculated on the basis of time rather than environmental performance and no criteria have been established to define acceptable standards against which operator responsibility can be assessed. Furthermore, as mentioned previously, residual landfills are largely based on the technology applied to contained landfills, and therefore feature the same negative characteristics ranging from the deterioration of lining and leachate drainage systems (Rollin *et al.*, 1991; Brune *et al.*, 1992) to the adoption of inadequate leachate minimization measures and related negative consequences .

The prevention of greenhouse gas emissions focuses mainly on the control of methane production by reducing the presence of biodegradable organic substances in waste. By contrast, scarce importance has been given to the important role of landfills in acting as 'carbon sinks', permanently sequestering the non-degradable biogenic carbon present in the waste.

Lastly, the 'Residual landfill', constituting a deposit for treated wastes and process residues, requires greater technical and environmental oversight than traditional landfills where raw waste is dumped. Residues may be characterized by higher concentrations of potentially polluting elements and an instability of material properties that need careful monitoring.

The modern type of landfill currently being developed on the basis of past experience, the findings of technical and scientific research and in response to ongoing environmental challenges, is the 'Sustainable Landfill' incorporating the positive aspects of past landfills (e.g. control of unsaturated foundations, containment and treatment of emissions, waste minimization and pretreatment) together with a coherent long-term strategy for the control of emissions and an awareness of climate change issues. Specifically, the sustainable landfill aims to achieve an environmental balance over one generation (20-30 years), controlling the accumulation of mobilizable substances and uncontrolled emissions, whilst on the other hand closing the material cycle (Cossu, 2009b), thus constituting a final geological deposit for inorganic substances, and

埋场封闭后管理测算，也没有制定相应标准对填埋场运营者的工作进行评估。而且，如前文所述，剩余废物填埋主要基于所采用的技术，因此同样存在衬层和渗滤液排水系统环损、渗滤液减量化不当等问题(Rollin et al., 1991; Brune et al., 1992)。

预防温室气体排放的主要措施是减少垃圾中可降解有机质。但对填埋场的“碳汇”功能，即：将不可降解的生物碳永久性地固定在填埋场中的作用却没有得到应有的重视。

最后，与传统填埋场相比，剩余废物填埋场更需要技术进步和环境监管。剩余废物很可能是高浓度潜在污染物，具有不稳定性，更需要仔细监测和监管。

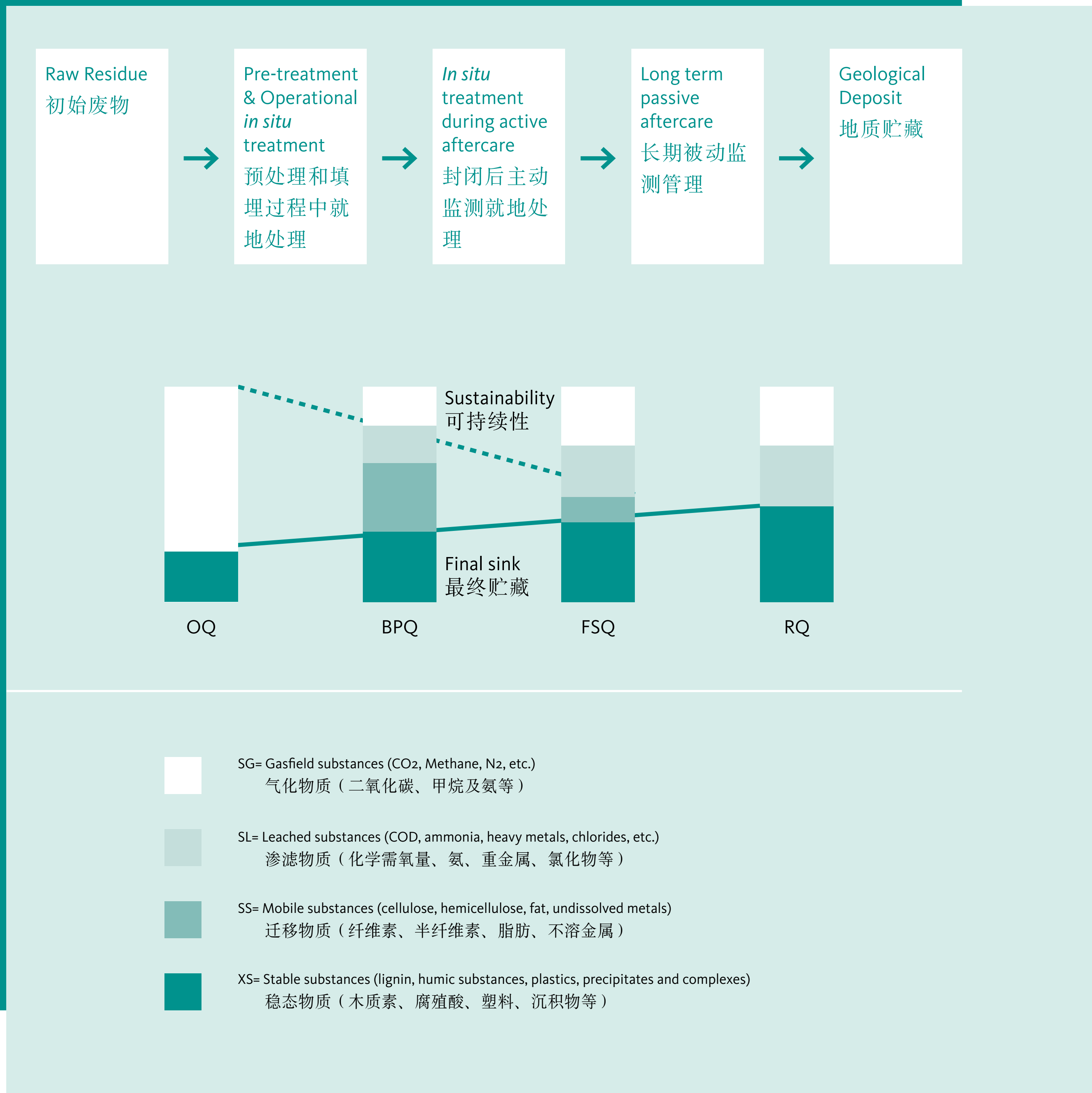
在总结过去经验基础上，充分吸纳科技进步成果，面对新的环境挑战，形成了现代填埋模式，即：可持续填埋。它既继承了过去填埋场的优点（例如，对不饱和基液进行控制，对污染物排放进行控制和处理，废物减量化、对废物进行预处理），也与时俱进提出对污染物进行长期控制的战略，并积极应对气候变化。具体来说，可持续填埋强调在代际间（20-30年）保持环境平衡，对排放物质和气体进行控制；并且强调遵守物质守恒定理(Cossu, 2009b)，将无机物，特别是与碳相关的不可降解或缓慢降解的物质，如塑料、橡胶、木材（不太便于回收的）、及可降解物质生物转化过程中产生的腐殖质等进行最终填埋。填埋场与海洋沉积物所发挥的作用相媲美(Bogner, 2005)。对高热值物质组分进行填埋，某种意义上也是为将来能源开发利用进行储备。

为了实现填埋场可持续发展，不仅应对废物进行预处理，而且还需要进行就地处理。机械生物预处理后或在强厌氧气体产生后进行就地好氧反应，经实践证明是保证最终填埋质量的重要工具，特别是对早期进行强制封闭覆顶填埋场，作用十分明显 (Stegmann and Ritzkowski, 2007)。

填埋场作为最终贮藏之现代作用

评价环境影响最关键的指标是对物质流的管理，应对它进行严格监测，避免在有机和无机物质间产生环境不平衡风险。所以应对废物处置过程中排放的物质（液体、气体和固体）进行短期和长期监测。在短时期内，应重点监测现场工作人员的工作环境、与废物管理设施毗邻的人群及生态系统。我们

Fig. 2: Scheme of the modern role of landfilling in waste management (OG = Original Waste Quality, BPQ = Best Practical Quality, FSQ = Final Storage Quality, RQ = Rock Quality).
图2: 符合现代废物管理理念的填埋场的作用 (OG = 初始阶段质量, BPQ = 最佳实践质量, FSQ = 最终贮藏质量, RQ = 岩石质量)



都知道世界各地公众对该问题都高度敏感。从长期角度来看，不仅为我们当代、还要为我们的子孙后代留下质量良好的环境（环境可持续性）。许多长期存在的环境问题如果管理不得当，在填埋场都会被放大。设想一下，焚烧产生的空气污染和不可降解物质在各种环境介质（水、土壤和底泥）中的累积。堆肥处理过程同样存在这些问题，并会留存污染物（如重金属等）。

对于各种类环境问题，应对污染控制挑战的关键因素是：当某些物质的数量或存在状态与自然环境不平衡时，如何减少这些物质的迁移。为了满足人类当前需要，我们从地下开采了所需要的地质资源（例如：矿物质、铁矿砂、石油等）。这些资源原本以非迁移状态、或不与环境直接接触的状态存在。为了满足某种生活方式的需要，我们将这些地下资源利用起来，但在其开采和使用过程中也产生了废物；并向环境“非故意排放”了这些物质。尽管有关规定允许低浓度排放，但这些物质造成了广泛环境污染。在全球范围内人们越来越多地暴露在重金属和持久性有机污染物存在的环境中，而这种污染往往是肉眼不可见、并且最难修复，是一种扩散性污染。环境工程师的任务就是检查并及时发现迁移和不迁移物质间的平衡，并尽可能在最短时间内将迁移物质回还到不迁移状态，从而降低暴露风险。

这个简单理论应该成为我们今天设计填埋场的指导思想。一方面，通过安装恰当屏障设施和对污染物进行充分处理，尽可能短期和长期减少渗滤液和沼气中的污染物，并在最短时间内让废物从质量和结构两方面，都具备条件实现填埋场和环境之间的平衡；另一方面，努力将填埋场建设成最终贮藏人类不再需要的、非迁移性物质的场所，至少在相当长一段时期内，我们希望将这些物质与环境彻底隔离（贮藏理念）。

关于物质及其组分的迁移性，针对废物我们可以做以下区分：

xS = 非迁移性、稳态固体(具有不溶性、不可降解性)

sS = 迁移固体

通过浸出、降解或其他反应，这种迁移物质可以从固态转化为液态（sL =浸出物质）或气态（sG=气化物质），或者转化成非迁移、稳态形式，并逐步增加xS组分。为了实现最安全保护系统，环

particularly for carbon associated with non-degradable or slowly degradable waste components such as plastics, rubber, and wood (when not more conveniently recycled) and with humic substances originating from the biological conversion of degradables. The role performed by the landfill as carbon sink is comparable to the role played by marine sediments (Bogner, 2005). Separate deposit of the high calorific constituents may also represent an intermediate storage option for future energetic utilisation of this material.
In order to achieve environmental sustainability in landfilling an important role is played not only by appropriate waste pre-treatment but also by *in situ* treatment measures such as flushing and, when in presence of a residual biological activity, aeration. 23
In-situ aeration, applied after Mechanical Biological Preatreatment or after intense anaerobic gas production, has proved to be an important tool in achieving Final Storage Quality, particularly where impervious top covers have been adopted at an earlier stage. (Stegmann and Ritzkowski, 2007)

Modern role of landfilling as a final sink

The key parameter in the assessment of environmental impacts associated with waste management is mass flow, which should be carefully monitored to avoid the risk of creating environmental imbalance for both organic and inorganic substances. The mass flow of emissions (liquid, gas, solid) associated with waste disposal needs to be monitored in both the short- and long-term. In the short term, this would imply the creation of acceptable environmental conditions both for onsite workers and for populations and ecosystems close to a waste management facility. We are all well aware of the increasing sensitivity of public opinion worldwide to these issues. In the long term, acceptable environmental conditions must be created not only for our own immediate future, but also for the future of generations to follow (environmental sustainability).
Long-term problems, many of which are more obviously manifested in landfills, may also be present with other waste management options if not managed carefully. Think of the impact of atmospheric emissions and the accumulation of non-degradable substances in various environmental sectors (water, soil, sediments) consequent on combustion. The same applies to compost and the contaminants contained therein (e.g. heavy metals).
As for all types of environmental issues, the key factor in controlling pollution is the challenge of limiting the mobility of those elements the quantities or form of which are not in equilibrium with the environment. For our immediate purposes we mobilize substances and elements from geological deposits (i.e. mineral and ore deposits, oil reservoirs) where they are present in a non-mobile form or in a form not directly in interaction with the environment. These substances are mobilized as we need them to meet the requirements of our life-style and in due course will contribute towards the generation of wastes during their

extraction and use, which processes may also in themselves entail a degree of uncontrolled distribution of these same substances into the environment. Even at the low concentrations permitted by regulations, such emissions may result in widespread environmental pollution.
Throughout the entire planet exposure to heavy metals and persistent organic pollutants is gradually increasing, which now constitutes one of the most subtle and least remediable forms of pollution: diffused pollution. The task entrusted to environmental engineers is to police the mass balance between mobilized and immobilized substances in such a way that the largest possible part of the substances mobilized returns in the shortest possible time to its non-mobile form, thereby minimizing the risk of exposure to uncontrolled emissions.
This simple principle should act as the main driver in designing a landfill today. On the one hand we should be able to guarantee, for both the short and long term, environmental protection by limiting the mobilization of substances present in leachate and in landfill gas – by installing appropriate barriers and treating emissions – whilst at the same time achieving, in the shortest possible time span, a final waste quality and overall structure capable of ensuring an equilibrium between the landfill and the environment. On the other hand, the landfill can act as a final sink for the stable, non-mobile substances which we no longer require and – at least in the medium term – wish to isolate from the environment (sink concept).
With regard to the mobility of elements and substances, in waste composition two distinct components can be identified:
x_S = non-mobile, stable solid components (insoluble, non-degradable)
s_S = mobile solid components
The mobile component (s_S) can be converted, by means of leaching, biodegradation or other reactions, from a solid to a liquid (s_L = leached component) or gas phase (s_G = gasified component) or alternatively into a non-mobile stable form that contributes towards increasing the x_S component. To achieve the safest protection system possible, environmental engineers must work to minimize the mobile component (s_S). This can be achieved by means of interventions undertaken both during the original manufacture of the product that will subsequently become waste (an aim that could be achieved by a rigorous implementation of EPR – Environmental Producer Responsibility), and/or during the phase of waste pretreatment before landfilling and/or by means of in-situ treatment during the operational phase of the landfill until the optimal waste quality envisaged by the type of treatment applied is achieved. This last objective could be defined as Best Practical Quality (BPQ), which is specific to the type of treatment used (Fig. 2).
Subsequently, the conversion of the mobilizable components may be further advanced, where necessary by means of additional treatment, during the aftercare phase, until a Final Storage Quality (FSQ) is reached, a

境工程师必须将迁移性组分 (sS) 降到最低程度。可以通过以下几个阶段逐步实现该目标：在产品最初生产阶段，减少废物产生（强制执行生产者责任延伸制）；在填埋前进行预处理，在填埋过程中进行就地处理，从而达到"理想废物"所要求的质量。可以将这个终极目标定义为符合处理要求的质量，即：最佳实践质量(BPQ) (图2)。
在填埋场后期管理过程，可加强对迁移性组分进一步转化，直到达到最终贮藏质量(FSQ)，即：达到了地质贮藏条件(图2)。与此同时，废物中有机物质的非迁移组分和无机物，在有机物转化过程中，也逐步被转化为不可降解物质（例如：不可溶腐殖酸）及其它沉积稳态无机物。实现上述目标，填埋场就真正变成了永久性地质贮藏区，物质循环系统也最终得以闭合。填埋场将温室气体稳定贮藏在地下，从这个角度讲填埋场具有更重要的意义。很多研究人员认为这种自然贮藏方式与海洋沉积物所发挥的作用可以相提并论 (Bogner, 2005)。

结论

填埋场作为废物长期填埋场所，不可避免地是控制污染物迁移或排放的有效措施。现代填埋场可以发挥两方面基础性作用：保护环境可持续性和实现最终地质贮藏。为了避免混乱，有必要对以下词汇进行清晰定义：可持续地质贮藏、地质填埋、贮藏填埋以及沉积填埋（sustainable geological repository, geological landfilling, sink landfilling, sedimentary landfilling）。

参阅资料

Bogner, J.E., 2005. From waste to resources: the evolution of waste management in Europe. In: P. Lechner (Ed.), Waste Management in the Focus of Controversial Interests. 1st BOKU Waste Conference Proceedings. Fakultas Verlag Publisher, pp. 14–22. ISBN 3-85076-721-3.
Bogner, J.E., 2005. Landfilling in the context of the global carbon cycle. In: Lechner P. (Ed.), Waste Management in the Focus of Controversial Interests 1st BOKU Waste Conference 2005, Publisher Facultas. ISBN 3-85076-721-3.
Brune, M., Ramke, H.G., Collins, H.J., Hanert, H.H., 1993. Incrustation processes in drainage systems of sanitary landfills. In: Proceedings Sardinia 91. Third International Landfill Symposium, CISA, Cagliari, vol. 1, pp. 999–1035.
Christensen, T.H., Cossu, R., Stegmann, R., (Eds.), 1992. Landfilling of Waste: Leachate. E&F Spon, an imprint of Chapman & Hall, London, 520 pp. ISBN 0-419- 16140-6.
Cossu, R., 2009. From triangles to cycles. Waste Management 29, 2915–2917.
Cossu, R., 2010. Technical evolution of landfilling. Waste Management 30, 947–948
Cossu, R., 2012. Geological repository Waste Management 32, 243–244
Rollin, A.L., Mlynarek, J., Lafleur, J., Zanescu, A., 1994. Performance changes in aged in-situ HDPE geomembrane. In: Christensen, T.H., Cossu, R., Stegmann, R. (Eds.), Landfilling of Waste: Barriers. E&F Spon, an imprint of Chapman & Hall, London, pp. 431–443.
Stegmann, R., Ritzkowski, M., (Eds.), 2007. Landfill Aeration. CISA Publisher. ISBN 978-88-6265-002-1.

demonstrable environmental equilibrium by the system has been achieved, and the active phase of aftercare can be said to be completed. Thereafter, the slower, natural diagenetic processes will in due course result in the achievement of an ultimate Rock Quality (RQ) at which point the landfill can be classed as a geological sink (Fig. 2). Such an integrated system of pretreatment and in situ operations, capable of progressively transforming the mass of mobile elements and compounds into leached or gasified compounds and into a low or immobile residue in equilibrium with the environment, will ultimately result in environmental sustainability. Concurrently, the non-mobile portion of organic compounds (i.e. lignin, plastic) and inorganic forms initially present in the waste (xS) will increase parallel to the conversion of biodegradable organic compounds into non-degradable substances (i.e. insoluble humic substances) and the precipitation and stable complex formation of inorganic substances.
In achieving the above goals, the landfill acts as a final sink, a long-term geological deposit which closes the material loop. This aspect is particularly important when considering the carbon sink role performed by a landfill in limiting the production of greenhouse gases. Numerous researchers maintain that this role may be of a similar importance to that carried out by such major natural sinks as marine sediments (Bogner, 2005).

Conclusions

To conclude, landfill, conceived as the long-term burial of waste, is an unavoidable virtuous system necessary to the control of the environmental mobility of elements. A modern landfill will be called upon to carry out two fundamental roles: environmental sustainability and final geological sink. New terms may be required for the waste deposition systems of the future in order to avoid confusion: sustainable geological repository, geological landfilling, sink landfilling, sedimentary landfilling.

References

Bogner, J.E., 2005. From waste to resources: the evolution of waste management in Europe. In: P. Lechner (Ed.), Waste Management in the Focus of Controversial Interests. 1st BOKU Waste Conference Proceedings. Fakultas Verlag Publisher, pp. 14–22. ISBN 3-85076-721-3.
Bogner, J.E., 2005. Landfilling in the context of the global carbon cycle. In: Lechner P. (Ed.), Waste Management in the Focus of Controversial Interests 1st BOKU Waste Conference 2005, Publisher Facultas. ISBN 3-85076-721-3.
Brune, M., Ramke, H.G., Collins, H.J., Hanert, H.H., 1993. Incrustation processes in drainage systems of sanitary landfills. In: Proceedings Sardinia 91. Third International Landfill Symposium, CISA, Cagliari, vol. 1, pp. 999–1035.
Christensen, T.H., Cossu, R., Stegmann, R., (Eds.), 1992. Landfilling of Waste: Leachate. E&F Spon, an imprint of Chapman & Hall, London, 520 pp. ISBN 0-419- 16140-6.
Cossu, R., 2009. From triangles to cycles. Waste Management 29, 2915–2917.
Cossu, R., 2010. Technical evolution of landfilling. Waste Management 30, 947–948
Cossu, R., 2012. Geological repository Waste Management 32, 243–244
Rollin, A.L., Mlynarek, J., Lafleur, J., Zanescu, A., 1994. Performance changes in aged in-situ HDPE geomembrane. In: Christensen, T.H., Cossu, R., Stegmann, R. (Eds.), Landfilling of Waste: Barriers. E&F Spon, an imprint of Chapman & Hall, London, pp. 431–443.
Stegmann, R., Ritzkowski, M., (Eds.), 2007. Landfill Aeration. CISA Publisher. ISBN 978-88-6265-002-1.

Different Landfill Models
固体废物不同填埋模式

Rainer Stegmann,
Hamburg University of Technology, Institute of Environmental Technology and Energy Economics
汉堡技术大学环境技术与能源经济研究所

Introduction

Landfilling is still by far the most diffused option in waste management worldwide. Due to increased waste avoidance and recycling, less waste will be landfilled in the future, but landfills will always be necessary in order to deal with the remaining non-reusable residual waste, acting in this sense as final sinks. There are still deficiencies in the design and operation of landfills today and there are different approaches in different countries. In many countries the waste is still disposed of in open dumps and there is an urgent need to introduce controlled landfilling in these cases.

Basic requirements for sustainable landfilling

Uncontrolled emissions from landfills and/or high landfill operational costs, e.g. due to remediation work, are often the results of inappropriate design and/or operation. In addition the cost of long term aftercare is often underestimated. There are basic requirements for landfill design and operation that have to be fulfilled; further, there is a pressing need to further improve landfilling in order to reduce the short, medium and long term emission potential of landfills at a much earlier stage. Landfill siting should respect appropriate geological and hydro-geological conditions, the ecological situation, distance from habitation, meteorological conditions and road access. In most cases some compromises have to be made where inadequate conditions can often be compensated for by means of additional technical installations. Landfills should be adequately lined at the bottom and the leachate should be collected and transported out of the landfill by means of an arterial drainage system with sufficient inclinations and the possibility of cleaning the drainage pipes periodically. The waste should be highly compacted and its mechanical stability must be guaranteed by installing adequate slopes. Low permeability soil should not be used as a daily cover. After the landfill is biologically stable the surface has to be lined, drained and covered with a sufficient amount of soil for vegetation. The collected leachate has to be treated meeting the required local standards and gas has to be captured as early as possible and recycled energetically as long as feasible (Christensen et al., 1989, 1992, 1994, 1996).

引言

到目前为止填埋仍然是当今世界应用最为广泛的固体废物处理方式。由于废物产生量逐步减少、废物循环利用率不断提高，将来填埋处理的废物也会越来越少。但是填埋方式永远都会有用，因为需要用它来接纳最终不能再利用的废弃残余物。这样，填埋就变成了废物最终收纳场。当前填埋场无论在设计、还是运行管理方面都存在缺陷，不同国家采用不同的填埋方法。许多国家仍然使用开放式填埋，因此急需引入控制型填埋处理方式。

可持续填埋的基本要求

造成填埋场无控制排放或产生高额运行费（例如修复工程）之原因，归纳起来基本上都可归咎于不恰当设计和/或者运行；并且经常出现对后期维护费用低估的情况。必须满足关于填埋场设计和运行的基本要求，而且应在早期对填埋进行改进提高以减少近、中期以及长期污染物排放。
填埋场选址要充分考虑地理、水文、生态、距离、气象及交通转运等条件。在大多数情况下由于某些方面条件不能满足，因此需要采取折中办法并通过安装其他设施来解决。
在垃圾填埋场底部应充分铺加底衬，应收集渗滤液并通过渗滤液排管系统将其导出。排管系统要有一定倾斜度以便于清洗。垃圾应完全压实并通过设计足够斜坡以确保其机械稳定性。低渗透土壤不宜作为日常盖土。当填埋场达到生物稳定后可以加盖封盖土，土层要有一定厚度，这样植被可以生长起来。对所收集渗滤液要进行妥善处理以达到当地排放标准，尽可能收集甲烷气体以作为能源利用。(Christensen et al., 1989, 1992, 1994, 1996).

不同填埋理念

发展中国家填埋 (DC)

开放式填埋在许多低收入国家仍然存在，即没有采取任何污染排放控制措施，直接将废物从上面下倒下去，并且不进行任何压实处理。这种垃圾倾倒场一般都位于环境比较敏感地区，坡度往往还比较陡。倾倒会带来很多问题，包括滑坡、失火、臭气、无控制渗滤液、污染物排放等等。此外，还存在食腐动物问题，因为这些填埋废物可能是有毒有害危险废物。因此，倾倒垃圾不仅带来技术、资金问题，而且可带来社会问题，应高度重视采取措施整治这类倾倒垃圾场以降低风险，并确保新建垃圾填埋场符合相关标准要求，避免重犯过去错误。发展中国家应对废物管理给予充分重视。

工业化国家垃圾填埋

由于各国情况不同，包括垃圾组分（例如高有机和高湿度废物）、气候条件、土地资源稀缺度（如日本）、地形地貌（如洛杉矶）、公众接受程度、法律法规到位情况、产业行业门类、废物焚烧程度等各不相同，因此各国填埋理念也不完全一致，有的国家把填埋场建在山谷或山上，有的建在坡地，也有建在在深挖矿井里等等。总体来说各国基本都执行上文中提到的关于垃圾填埋场的基本要求，但也都不同程度犯了很多错误。
许多垃圾填埋场部分或全部建在水平面以下，这意味着必须“永远”通过泵将垃圾渗滤液从收集点中抽出。维护和清洗渗滤液收集管系统则变得非常复杂。当填埋场为顶衬设计，当渗滤液缓慢渗出、并且/或者顶衬出现坏损，在一定时期后渗滤液就会产生（尽管在这种情况下渗滤液流速不快）；但除非把填埋场搬走，否则渗滤液永远都会集中在那里。由于这类或其他原因，作者强烈建议将垃圾填埋场建设成土丘形状，这样可依靠重力将渗滤液压出填埋坑。
围绕垃圾填埋存在许多不同观点。在很多国家有明确规定：一旦填埋场达到既定高度，必须立即封盖覆顶。而在这种情况下，由于缺乏水分和/或液体流动（干燥墓穴概念），往往没有留出时间进行生物反应。衬层是有使用寿命的，当填埋场封闭或不再对它进行监控后，往往会出现液体渗

Different Landfill concepts

Landfilling in economically developing countries (DC)

In many low-income countries open dumps are still in operation. This means that no emission control takes place, the waste is often discharged top down and not compacted. The dumps are often located in environmentally sensitive areas and slopes may be very steep. This method of dumping results in a variety of problems, such as landfill sliding, fires, littering, odors, uncontrolled leachate and gas emissions, etc. In addition there is the problem of scavengers, who are subjected to all kinds of hazards from toxic waste and fumes etc. Waste dumping is therefore not only a technical and financial but also a social problem. It is an enormous but extremely important task to clean up existing dumps in order to limit the danger they pose and to build new landfills to an adequate standard avoiding mistakes made in the past. Waste Management needs to be awarded a higher priority in developing countries.

Example for a reused landfill: Landfill Leppe, Germany
德国Leppe垃圾填埋场的再利用

Landfilling in industrialized countries

Landfill concepts are different worldwide due to different waste composition (e.g. high organic or high moisture content), climatic conditions, land availability (e.g. Japan), morphology of the land (e.g. mountain areas, Los Angeles), public acceptance, legislation, kinds of industry, degree of waste incineration, etc. Landfills are built in valleys or on mountains, attached to mountain slopes, in excavated open or deep mines, etc. The above mentioned basic requirements are more or less taken into account in most cases, but still many mistakes are made.
Many landfills are built partly or entirely below the surface which means that leachate has to be pumped out of the collection sumps in perpetuity and furthermore the maintenance and cleaning of the drainage system is more complex. Also when landfills are lined at the top, leachate production – even at a low rate – can still be expected, due to the slow release of accumulated

入填埋场情况。在这种情况下，生物反应会再次剧烈发生，并产生渗滤液和沼气。这种填埋场理念只适用于不可降解废物或无机危险废物；对于可降解废物（如生活垃圾），则应该引入生物反应池的概念。
在工业化国家，老垃圾填埋场出现的问题越来越多，在填埋场封闭后，渗滤液收集和沼气控制问题非常突出。因此必须对填埋场进行监测和维护；如有必要还需进行设施维修，这样需要花费较高费用。如果在初期能够按照生物反应池的概念设计和运行管理填埋场，并在填埋场封闭后进行合理管理（如采用就地好氧处理措施），这样可大大降低排放 (Heyer, et.al., 2007)。

生物反应器型填埋场

在较短时间内降低排放，需在早期大量减少气体聚集并降低渗滤液浓度。生物反应池填埋场出现很多问题，其中最重要的环节是如何确保渗滤液以可控方式进行循环。
控制渗滤液循环可大大提高生物反应过程，在早期即可实现产生甲烷反应。而且易降解化合物在较短时间内随液体渗出，水分含量和水通量也可在较短时间内提高，这样大大提高生物反应效率。渗滤液循环过程也是对其进行处理的过程；事实上，应对循环渗滤液进行生物（预）处理。此外应避免形成渗滤液集中塘。
作者还强烈建议每层生活垃圾上铺放的薄土 (± 50 cm)要压实，作业面积不可太小，以避免在填埋场表面发生好氧降解 (Stegmann, 1995)。
为降低有机渗滤液浓度，根据德国填埋场成功经验，作者建议在渗滤液收集系统砾石顶部，铺放厚度为1-2米的混带有结构材料的生活垃圾层。这种混合垃圾层可对废物上层流下来的渗滤液发挥厌氧过滤作用，这样易降解有机物可部分转化为沼气 (Stegmann, 1995)。
在填埋场服役过程中，不仅通过“不断增长”的竖井来抽取填埋气，而且还可成功通过水平系统抽取气体。当所产生的甲烷气体不足以被实际利用、火炬很难维持时，可考虑采取就地好氧填埋措施。大多数情况下填埋场气压较低，通过这种方式剩余有机物质很快被好氧降解，并且降解程度很高。实践证明，这种技术可以很好控制填埋气排放(Heyer, et.al. 2007)。最后在填埋场顶加盖

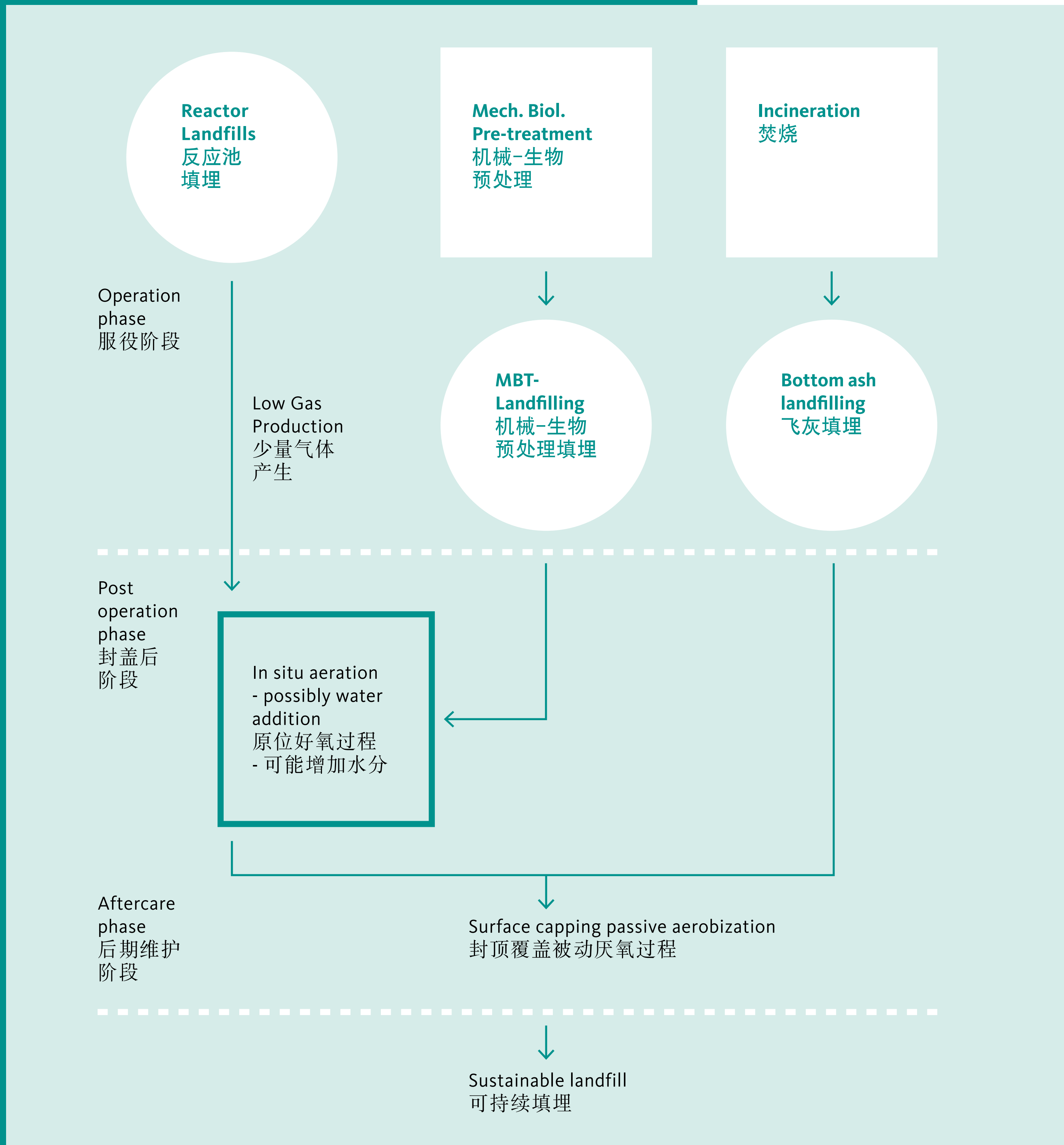
Open dump in Addis Abeba
亚的斯亚贝巴的敞开式垃圾场

leachate and/or due to failures in the top cover liner, which can be expected after a certain period of time (landfills persist in perpetuity, unless they are removed). For this and other reasons the author strongly recommends the construction of landfill mounds where gravity will suffice to induce the leachate to leave the landfill through the drainage system.
A discussion central to landfill operations is still going on: in many countries it is prescribed that the landfill or a section thereof be immediately sealed once it has reached its final height. In this case biological processes may be inhibited due to a lack of water and/or water movement (dry tomb landfill concept). Liners, besides, have a certain lifetime; as a consequence water may enter the landfill when there are no longer ongoing landfill operations or supervision. At that point the biological processes will be intensified again and leachate and biogas will be produced. This landfill concept should only be applied to non-biological degradable waste as distinct from inorganic hazardous waste and other kinds of inert waste. For waste with degradable compounds (e.g. municipal solid waste, MSW) the bioreactor concept should be used.
In industrialized countries the problem of old landfills has become increasingly evident. After closure, leachate has still to be treated and gas has to be controlled. The landfills have to be further inspected and maintained and if necessary landfill installations have to be repaired. These activities may entail high costs. Cost savings can be achieved if the landfills are operated as bioreactors reducing the emission potential as early as possible and if adequate aftercare measures are taken to reduce the longterm emission potential e.g. by using in-situ aeration (Heyer, et.al., 2007).

Bioreactor Landfills

When reducing the emission potential of a landfill in a significantly shorter period of time, gas production is concentrated within a shorter timespan and leachate concentrations are significantly reduced earlier in

Fig. 1: Sustainable landfill concept
图1: 可持续填埋理念



"不透水"衬层。一旦衬层将来出现泄漏，由于填埋场甲烷气体已经降到很低程度，因此可将所产生的环境影响控制在"可接受的水平"。在填埋场封顶后，还需要进行长期低量甲烷气控制。

半好氧填埋 / Rottedeponie

提高降解效果的另一种方法是半好氧填埋。这种技术在日本和其他一些国家应用比较广泛。在填埋场底部铺设管道，管口直通外面空气，这样就在填埋场里形成烟道效应。由于填埋场内温度较高，空气被吸入并直达填埋场底部。日本填埋垃圾有机成分较低，因此起初这种技术在日本填埋场应用较多；尽管亚洲垃圾的有机成分较高，但如今很多国家填埋场也都采取了这种技术(Matsufuji, 2004)。目前还没有看到很多关于这类填埋场效果方面的文章。

机械-生物预处理垃圾填埋场

在欧洲特别是德国和奥地利，明确规定禁止填埋有机组分垃圾，因此要求在填埋前采用机械生物技术对垃圾进行预处理。用机械技术将高热值生活垃圾组分筛除出去；对孔径较小未筛除掉的组分则通过生物技术降低其热值。这样垃圾排放潜力降低，甲烷气体产生量和渗滤液浓度都会相应降低。通过生物预处理大约减少80 - ± 90 % 的可降解有机质，但仍未达到最终填埋控制质量。

飞灰填埋

垃圾焚烧厂产生的飞灰仍有排放污染物的可能性，因此不能被当作"惰性"垃圾来处理。Lichtensteiger (1995) 认为飞灰在高温条件下（高达80 – 90 °C）发生化学/物理反应，因此未处理飞灰填埋是一种活性填埋，在这个过程中可能会产生氢气，并且其渗滤液氯、碳酸盐、硫酸盐浓度较高（在克/升这个数量级范围内）。特别是在填埋初期，出现氮和溶解碳（< 100mg/l）上升的现象。根据飞灰质量不同，可考虑严格执行惰性废物处理标准、或略宽松些惰性废物处理标（D+D 废物）（德国分类I级）（无名, 2000）。德国对危险废物（III类）和I类填埋场的管理理念是将其彻底隔离，一旦填埋场（或填埋部分）停止运行，就将其彻底封盖，这样避免填埋场产生排气可能性（图1）。

the cycle. A degree of mystery surrounds bioreactor landfills, but what is meant in most cases, is that leachate is recirculated in a controlled way.
Controlled leachate recirculation enhances the biological processes in order to reach the methane phase at an early stage. In addition, easily biodegradable compounds are leached out in a shorter period of time and the water content as well as the water flow are increased. As a result the biological processes are enhanced. Leachate recirculation in most cases will not make leachate treatment obsolete, in fact the recirculated leachate should ideally be biologically (pre-) treated. In addition leachate ponding in the landfill has to be avoided.
As additional measures the author strongly recommends the emplacement of the municipal solid waste in highly compacted thin lifts (± 50 cm). The operational area should not be so small as to preclude some aerobic degradation processes at the landfill surface. (Stegmann, 1995).
In order to reduce the organic leachate concentrations the author recommends – this has proved to be effective at several landfills in Germany – the putting in place of a 1-2 m layer of composted MSW containing sufficient structural material on top of the gravel layer of the leachate collection system. This composted waste layer acts as an anaerobic filter for the migrating leachate from the upper waste layers. By these means the easily degradable organics are partly anaerobically converted to biogas (Stegmann, 1995).
Landfill gas should also be extracted during the operational phase where, in addition to 'growing' vertical wells, horizontal gas extraction systems may be used successfully. When gas production has decreased to a level that gas utilization is no longer feasible and even flaring causes problems, in-situ aeration of the landfill is recommended. In most cases air will be injected into the landfill at low pressure and extracted again. By these means the remaining organic substances will be aerobically degraded much faster and to a higher degree. Using this proven technology a very low emission potential can be achieved (Heyer, et.al. 2007). Finally the landfill should be covered with an 'impermeable' liner. If any leakage occurs in the future, the environmental damage will be at an acceptable level, due to the low emission potential of the landfill. Long-term low volume gas control may also be necessary after the landfill has been capped (Fig. 1).

Semi-aerobic landfill – Rottedeponie

Another way to enhance degradation processes is the semi-aerobic landfill. This landfill type is operated at several sites in Japan and elsewhere. In this case pipes are installed at the bottom of the landfill open to the atmosphere, being constructed as chimneys inside the landfill in order to create the so called 'chimney effect' where due to higher temperatures in the landfill body air is sucked into the landfill from the bottom. Initially this system was used at Japanese landfills where the constituent waste has a comparatively low organic content. Nowadays this concept is also applied in some Asian landfills where the organic content of the landfilled waste is significantly higher (Matsufuji, 2004). Insufficient results recording the efficiency of this process at full-scale landfills are currently available.

Landfills for mechanically-biologically pretreated waste

Where legal measures are in place prohibiting the landfilling of the organic degradable portions of waste in Europe, esp. in Germany and Austria, mechanical biological pretreatment (MBP) prior to landfilling has been employed. During mechanical pretreatment the high calorific value fraction of municipal solid waste (MSW) is removed mainly by sieving and this fraction (known as the undersized fraction) is biologically treated to very low values. This material has a relatively low emission potential which means that only a limited degree of gas production will occur and leachate concentrations will also be comparatively low. Although about 80 to ± 90 % of the degradable organics have been degraded during the biological pre-treatment step the landfill will still not have reached the final storage quality.

Landfills for bottom ashes

Bottom ashes from waste incinerators have an emission potential and cannot therefore be described as "inert". Lichtensteiger (1995) described a bottom ash landfill for non-pretreated ashes as an active landfill since chemical/physical processes take place while high temperatures (up to 80 – 90 °C) may occur. In addition hydrogen gas may be produced. Leachate data show relatively high chloride, carbonate and sulphate concentrations (in the range of g/l). Especially in the early stage of landfilling elevated concentrations of nitrogen and DOC (< 100mg/l) can also be expected. Depending on the ash quality the bottom ash landfill may have to respect the same criteria as MSW landfills (class II) or the somewhat less stringent criteria valid for inert waste landfills (former D+D waste) (German Category I) (Anonymous, 2000).
The procedure for hazardous waste (class III) and class I landfills in Germany involves protection of the waste by means of surface capping once the landfill/landfill section is no longer operative. By these means the emission potential of such a landfill will be contained. The author presents in Figure 1 a scheme of a sustainable landfill concept (Fig. 1).

Conclusions

Due to the high emission potential of MSW landfills and their long term emissions that can persist for decades or even longer, the natural biological processes in the landfill should be enhanced and the emission potential reduced as early as possible. Either in-situ

结论

由于生活垃圾排气可能性较大，并且这种排放可持续几十年甚至更长，因此应提高填埋场生物处理技术，并在初期尽可能降低排放潜力。原位处理技术(生物反应池填埋，原位好氧) 或异位处理技术（机械-生物或热处理）均可考虑采用，其中后者效果更好、但成本也更高。只有当生物降解基本结束、排气潜力基本消除后，才可对填埋场进行封盖。作者认为，大多数国家可考虑采用生物反应池型、带有原位处理顶盖覆衬的填埋场技术。如前文所述，在废物有机组分较低情况下，可在进行热处理、机械-生物预处理（MBT）后可进行填埋。但MBT只适用于过渡阶段。
避免废物产生、加强循环利用才是未来的出路，也只有这样才能持续减少填埋废物量。从长远来讲，填埋仍然是最终处置废物的选择。

参考文献

Matsufuji, Y., 2004, A road to Semi-aerobic Landfill – Experience of semi-aerobic landfilling in Japan and Malaysia. The 3rd Intercontinental Land Research Symposium, November 29th – December 2nd, Hokkaido, Japan
Stegmann, R. (1995). Concepts of Waste Landfilling. In: Christensen, T.H., Cossu, R., Stegmann, R. (Eds.), SARDINIA 95, Vol. I, pp. 3-12. CISA, Via Marenago 34, 09123 Cagliari, Italy
Anonymous, (2000), Verordnung über die umweltverträgliche Ablagerung von Siedlungsabfällen und über biologische Behandlungsanlagen – http://www.bmu.de
Christensen, T.H., Cossu, R. and Stegmann, R. (Eds.) (1996), Landfilling of Waste: Biogas, E&FN Spon, London
Christensen, T.H., Cossu, R. and Stegmann, R. (Eds.) (1989), Sanitary Landfilling, Academic Press Limited, London
Christensen, T.H., Cossu, R. and Stegmann, R. (Eds.) (1994), Landfilling of Waste: Barriers, E&FN Spon, London
Christensen, T.H., Cossu, R. and Stegmann, R. (Eds.) (1992), Landfilling of Waste: Leachate, Elsevier Applied Science
Lichtensteiger, T. (1995), Deponieverhalten von Schlacken aus Rostfeuerungsanlagen (Landfill behaviour of bottom ashes from MSW-incinerators), In: Gallenkemper, Bidlingmaier, Doedens and Stegmann (Eds.), 4. Münsteraner Abfallwirtschaftstage, Fachhochschule Münster, Heft 8, Eigenverlag
Heyer, K-U., Hupe, K.,Koop, A. and Stegmann, R., (2007) Aerobic in situ aeration of landfills: longterm experience and new developments, SARDINIA, 2007, Proceedings, 11. International Waste Management and Landfill Symposium,CISA, Contact: EuroWaste Srl,Padova, Italy

(Bioreactor Landfill, In-Situ Aeration) or ex-situ measures (mechanical biological or thermal pretreatment) should be practiced with the latter being actually the more efficacious but also more costly approach. The landfill should be capped only when the biological degradation rates have come almost to an end and the emission potential is low. Only those landfills where biologically or thermally pretreated waste as well as hazardous and inert waste is disposed of should be capped directly after a landfill or a landfill section has been completed. In the view of the author the bioreactor landfill with in-situ treatment and top liner might the preferred option in most countries. Where it is legally prescribed that only waste with a very low organic content can be landfilled, either thermal or mechanical-biological pre-treatment is required where mechanical biological treatment (MBT) may only be used for a limited period of time.
In the future we should see more waste avoidance and recycling so that the landfilling of waste can be steadily reduced. In the long term landfills will continue to be needed to act as a final sink for the remaining residues.

References

Matsufuji, Y., 2004, A road to Semi-aerobic Landfill – Experience of semi-aerobic landfilling in Japan and Malaysia. The 3rd Intercontinental Land Research Symposium, November 29th – December 2nd, Hokkaido, Japan
Stegmann, R. (1995). Concepts of Waste Landfilling. In: Christensen, T.H., Cossu, R., Stegmann, R. (Eds.), SARDINIA 95, Vol. I, pp. 3-12. CISA, Via Marenago 34, 09123 Cagliari, Italy
Anonymous, (2000), Verordnung über die umweltverträgliche Ablagerung von Siedlungsabfällen und über biologische Behandlungsanlagen – http://www.bmu.de
Christensen, T.H., Cossu, R. and Stegmann, R. (Eds.) (1996), Landfilling of Waste: Biogas, E&FN Spon, London
Christensen, T.H., Cossu, R. and Stegmann, R. (Eds.) (1989), Sanitary Landfilling, Academic Press Limited, London
Christensen, T.H., Cossu, R. and Stegmann, R. (Eds.) (1994), Landfilling of Waste: Barriers, E&FN Spon, London
Christensen, T.H., Cossu, R. and Stegmann, R. (Eds.) (1992), Landfilling of Waste: Leachate, Elsevier Applied Science
Lichtensteiger, T. (1995), Deponieverhalten von Schlacken aus Rostfeuerungsanlagen (Landfill behaviour of bottom ashes from MSW-incinerators), In: Gallenkemper, Bidlingmaier, Doedens and Stegmann (Eds.), 4. Münsteraner Abfallwirtschaftstage, Fachhochschule Münster, Heft 8, Eigenverlag
Heyer, K-U., Hupe, K.,Koop, A. and Stegmann, R., (2007) Aerobic in situ aeration of landfills: longterm experience and new developments, SARDINIA, 2007, Proceedings, 11. International Waste Management and Landfill Symposium,CISA, Contact: EuroWaste Srl,Padova, Italy

Landfill Leachate Management
填埋场渗滤液管理

Yue Dongbei,
Division of Solid Waste Management, School of Environment – Tsinghua University
岳东北，清华大学环境学院固体废物控制与资源化教研所

Contaminants carried or generated by municipal solid waste in landfills are released into the environment via the following three routes. First, the pollutants may be emitted into the atmosphere from a point source or a fugitive emission at working surfaces or through intermediate/final cover systems. Second, the contaminants may infiltrate the bottom liner system of a landfill and migrate to groundwater. Last but not least, the contaminants can be released in liquid form, such as leachate, polluted rainwater, condensate, and so on. The above mentioned three emission types are currently encountered in most counties where the management and supervision of the secondary pollution from landfills is practised. However, not all countries are placing the same importance on all these possible emissions.

In order to minimize the groundwater contamination resulting from municipal solid waste landfills, it is required in most countries that the head of leachate above the bottom liner system within a landfill must not exceed 30 cm. However, the implementation challenges are totally different in different regions. Practically speaking, it is much easier to control the leachate head at landfills of Europe or the US than at those in China. At a number of Chinese municipal solid waste landfills, the leachate level within a landfill rises as the height of the landfill increases. This situation may be attributed to the characteristics of the municipal solid waste or to the landfilling methods employed. The former is likely to be more significant. For instance, the composition of discarded municipal solid waste in the US in 2012 included paper (14.8%), plastic (17.6%), wood (8.2%) and metal (9.0%). In contrast, 47.5% of landfilled municipal solid waste in Beijing in the same year was food waste, the water content of which is extremely high, while recyclable components were hardly present at all. The presence of large amounts of food waste with high water content leads to abnormal water distribution and flow within landfills. The leachate generation of Chinese landfills is usually estimated according to the amount of municipal solid waste to be landfilled, significantly different from Europe and the US where the leachate generation is always based on a rule of thumb estimate of precipitation.

Landfill leachate is hard to deal with due to its complex composition, high contaminant concentration and

填埋场污染物的释放主要有三个途径：通过填埋场作业面或场顶覆盖层以点源或无组织扩散的形式向空气释放、通过填埋场底衬层向地下水渗透与迁移、以渗滤液或受污染雨水或其它废水的形式释放。目前多数国家对填埋场二次污染的监管对上述三种释放途径都有所涉及，但重视程度不完全相同。

为了尽可能降低填埋场对地下水的污染威胁，多数国家要求填埋场底部衬层上渗滤液水头不超过30 cm，但是实施的效果不一样。欧美国家的填埋场渗滤液水头较为容易控制，但是在中国则遇到了很大麻烦。中国的很多生活垃圾填埋场都出现了“垃圾增、渗滤液升”的问题，其原因可能在于垃圾特性和填埋操作方式，而前者更为重要。以2012年为例，美国进入填埋场的垃圾中，废纸、塑料、木制品、金属分别占14.8%、17.6%、8.2%、9.0%，食品类垃圾仅为21.1%【源自美国EPA数据】；而同年北京市进入填埋场的垃圾中，47.5%为食品类垃圾，且具有极高的含水率，可回收类成分几乎没有。高含水率的食品类垃圾大量进入填埋场导致了水分分布与流动的异常。中国填埋场渗滤液产生量的经验估算主要由生活垃圾填埋量决定，与主要通过降雨量来估算渗滤液量的欧美等国家有着显著的不同。

填埋场渗滤液由于成分复杂、浓度高、波动大而难于处理，几乎所有的水处理工艺在渗滤液处理领域都有应用，既包括传统的生物、物理、化学等方法，也有膜过滤、高级氧化等新兴技术。渗滤液处理技术与工艺的选择需要考虑技术效果、经济成本、环境容量及排放要求等因素，但主要由排放要求和经济成本共同限定了可选择的技术范围。

世界各国对于填埋场渗滤液的排放标准要求千差万别。相对而言，美国较为宽松，欧洲较为

严格，而中国最为严格。美国没有对COD进行限制，考虑到填埋场废水及处理效果的合理波动，给出了每日最大负荷和月平均最大负荷两类限值，给予填埋场很大的自主权和灵活执行的空间。美国Waste Management公司旗下的填埋场大多将渗滤液输送至污水处理厂，其余则采用回灌、蒸发等处理方式。

相比较而言，中国的排放限值非常严格，每一个填埋场必须在现场完全建设一套工艺流程比城镇污水处理厂高级得多的渗滤液处理设施。排放要求高自然有利于生态环境的保护，但是当排放要求过于严格时，则实际上限制了渗滤液处理技术的选择，只有相当有限的实用技术可以达到该排放标准，或者说，只有通常用于高级饮用水处理的膜处理技术才能满足该排放限值。这种情况下，填埋场运营者没有任何选择余地，只能选择这种建设投资大、运营成本高的高端处理技术。使用膜处理技术可以使得排水达到相当高的标准，但是它只是一个物理截留过程，污染物被富集在膜浓缩液中，而现行标准没有明确这部分浓缩液该如何处理。实际情况是相当一部分浓缩液被转移至污水处理厂，实则是“污染物先浓缩、再转移”。同时，也使得相当多的填埋场因为达不到这么高的要求而放弃了处理渗滤液的积极努力。这就使得通过制定如此严格标准来在填埋场现场削减污染物的努力化为泡影。

因此，渗滤液处理排放标准的制定不能过于超前，应该考虑技术发展的实际情况，给填埋场在渗滤液处理技术与工艺上的选择权，从污染物的实际削减与去除目的出发，综合考虑环境效益与经济成本的平衡关系。“适当的削减”始终是一个比“不处理”或“高成本的转移”更优的选择。

还需要注意的是，对渗滤液处理的重视并不能替代对填埋场地下水的污染控制，还需要关注场内积存渗滤液的问题。填埋场渗滤液的污染特性是显性的、较为容易实施控制的，而污染物向地下水和土壤的渗透则是隐性的、较难监测或实施控制的。污染物通过填埋场衬层向地下水渗透与渗滤液收集有一定的相互影响。填埋场内部污染物向地下水迁移，水是重要载体，因此控制垃圾内部的水位高度（水头压力）对于填埋场地下水污染控制很重要。如果渗滤液因收集不及时或效率不高而积存在填埋场内部，就会使得场内水头压力增加，进而增加污染物向地下水渗透的速率。尽管从理论上讲，渗滤液渗漏只有当防渗层系统破损时才会发生，但是不论填埋场施工人员、运行人员还是环保部门监管人员都清楚这个事实：防渗层破损只能尽可能减少，不可能完全避免。在防渗层破损无法避免的情况下，控制填埋场内水位高度对于降低填埋场对场底地下水污染风险至关重要，也应该是填埋场渗滤液管理的重要内容之一。

fluctuant characteristics. Consequently, almost all the techniques and processes regularly employed for dealing with water and wastewater have been applied to leachate treatment, including not only traditional biological, physical and chemical methods, but also a number of emerging technologies such as membrane filtration, advanced oxidation, etc. Many factors need to be taken into account when choosing between leachate treatment techniques, including treatment efficiency, construction investment and operational cost, environmental capacity, discharge requirements, and so on. Among the most important of these are discharge requirements and construction investment and operation, which may seriously limit the range of practicable technical options for leachate treatment.
Requirements governing the disposal of landfill leachate differ from country to country. Relatively speaking, the national requirements in the US are less strict than those in the European countries, while China has the most restrictive standards. There is no maximum set on chemical oxygen demand (COD) when treated leachate is discharged in the US, and daily and monthly peak limits are used when considering the actual fluctuation of landfill leachate characteristics and its treatment reasonable for a particular landfill operation. Most landfills operated by waste management enterprises in the US, for instance, transport leachate to public sewage treatment plants, and recirculation, evaporation and other techniques are also used for leachate treatment at the remaining landfills.
Comparatively, discharge requirements on landfill leachate are really stringent in China. The leachate must be treated on site and an integrated treatment facility must be built, which is generally more advanced and complex than that for sewage treatment. While it is indisputable that higher discharge requirements are more beneficial to environmental protection, nevertheless the choice of leachate treatment technologies actually becomes quite limited once the discharge requirements are too strict. There are relatively few viable operative technologies that meet the discharge standard. In fact, only the membrane techniques commonly used for advanced drinking water treatment can fully meet the discharge limits and landfill operators therefore have no other choice but choose this very high-tech method with its extremely expensive investment in equipment and operating costs. With the application of membrane filtration technology, the effluent quality can reach quite a high standard, but the pollutants are then concentrated in the retention sump since there has been no more than a physical separation up to this point. Unfortunately, under the current standards regime there are no specific requirements for the retained contaminants. As a matter of fact, a quite substantial part of the concentrate is being quietly transferred to sewage treatment plants. That is to say, the pollutants are transferred for further treatment following an expensive process of concentration, which is actually not necessary in the circumstances. Moreover, a considerable amount of landfills have to give up their efforts to treat leachate because they cannot meet the requirements anyway. The expectation was that the pollutants would be reduced by implementing stricter criteria, but that has evidently not proved to be the case.
It would appear therefore, that the practicalities of landfill leachate management should be afforded greater consideration when deciding the criteria for leachate discharge. Landfill operators should be allowed more latitude when planning how to deal with the problem of leachate. Meanwhile, bearing in mind that the target is always pollutant removal, keeping the balance between environmental benefits and economic cost is also of great importance. In other words, compared with ‘doing nothing’ or ‘incurring exorbitant costs merely to shift pollution from one place to another’, reducing pollution to the greatest achievable extent is always a better choice.
Besides paying due attention to leachate treatment, the management of cumulative leachate inside the landfill is an equally important issue from the point view of groundwater protection. Threats from landfill leachate pollutants are easy to recognize, and the pollution can be controlled if the effort is made. On the other hand, pollutant permeation of groundwater and soil is much less visible, and is consequently very difficult to monitor or control. Leachate permeation through liners and leachate collection are interconnected. Water is an important carrier when pollutants migrate from landfill to groundwater or soil. As a result, controlling the water height (head pressure) on the bottom liner inside a landfill is critical for preventing groundwater pollution. Leachate accumulates inside the landfill if is not collected promptly and efficiently, leading to an increase of head pressure and the consequent permeation of pollutants through to groundwater. Theoretically, leachate leakage should only occur in the event of damage to the impervious layer system. In practice, however, damage to the impervious layer can only be reduced as much as possible, but cannot be avoided completely. This being the case, keeping an eye on water height inside landfills is crucial in reducing the risk of groundwater pollution and should also be counted an essential part of leachate management.

MSW Landfilling in China: Past, Present and Future

中国生活垃圾填埋的过去、现在和将来

He Pinjing *[1,2], Lü Fan [1,2], Zhang Hua [1,2], Shao Liming [1,2]
何品晶 *[1,2]吕凡 [1,2]章骅 [1,2]邵立明 [1,2]
1. Institute of Waste Treatment and Reclamation, Tongji University
2. Centre for the Technology Research and Training on Household Waste in Small Towns & Rural Areas, Ministry of Housing and Urban-Rural Development of P R. China (MOHURD)
* Corresponding author: solidwaste@tongji.edu.cn
1. 同济大学固体废物处理与资源化研究所
2. 住房和城乡建设部村镇建设司农村生活垃圾处理技术研究与培训中心
* 通讯作者: solidwaste@tongji.edu.cn

Past

In China, the demand for treating municipal solid waste (MSW) has burgeoned since the 1980's. Rapid economic development has spurred an increasing generation of MSW, and at the same time rendered its composition more and more complex. Components such as plastics which were incompatible with natural soils emerged in MSW. As a result, the MSW could no longer be safely applied to suburban farmlands. Many cities had to dump the MSW in uncultivated lands or even (notwithstanding the above) in farmlands. This produced the so-called "Garbage around the City" phenomenon which had a serious impact on the surrounding environment.
Faced with an urgent demand for MSW treatment, and with economic cost an important factor, the Chinese government proposed a technical approach to MSW disposal mainly based on lanfilling (Reference: The document "The State Council Authorizes the Ministry of Construction to Treat Municipal Solid Waste" issued by The State Council on July 4, 1992.). As a result, landfilling bcame the main instrument for MSW treatment in China, and up until the present time it is still the dominant measure. Figure 1 shows the annual total amount of MSW collected and treated, as well as the amounts separately treated by landfilling, incineration and biological technology in the years 1980 to 2012.
The figure shows that the treatment level of landfilling was low before Year 2000, mainly because that the liner and the leachate treatment could not meet the required technical standards (specifically: Chinese Standards on Landfilling, No. CJJ17-88 and No. GB16889-1997). (Fig. 1)

Present

From the year 2000, China issued the Sanitary Landfilling Technical Standard (CJJ17-2004), which had similar requirements to the standards in Europe and United States. For example, it was required to employ composite liner. And the Standard GB 16889-2008 sets strict limit values for leachate treatment and discharge (as shown in Table 1), and encourages the collection and utilization of landfill gas. Consequently, the treatment level of landfilling in China was significantly improved.
At present, given the specific composition of MSW in China, a number of special landfilling technologies have been developed for Chinese MSW.

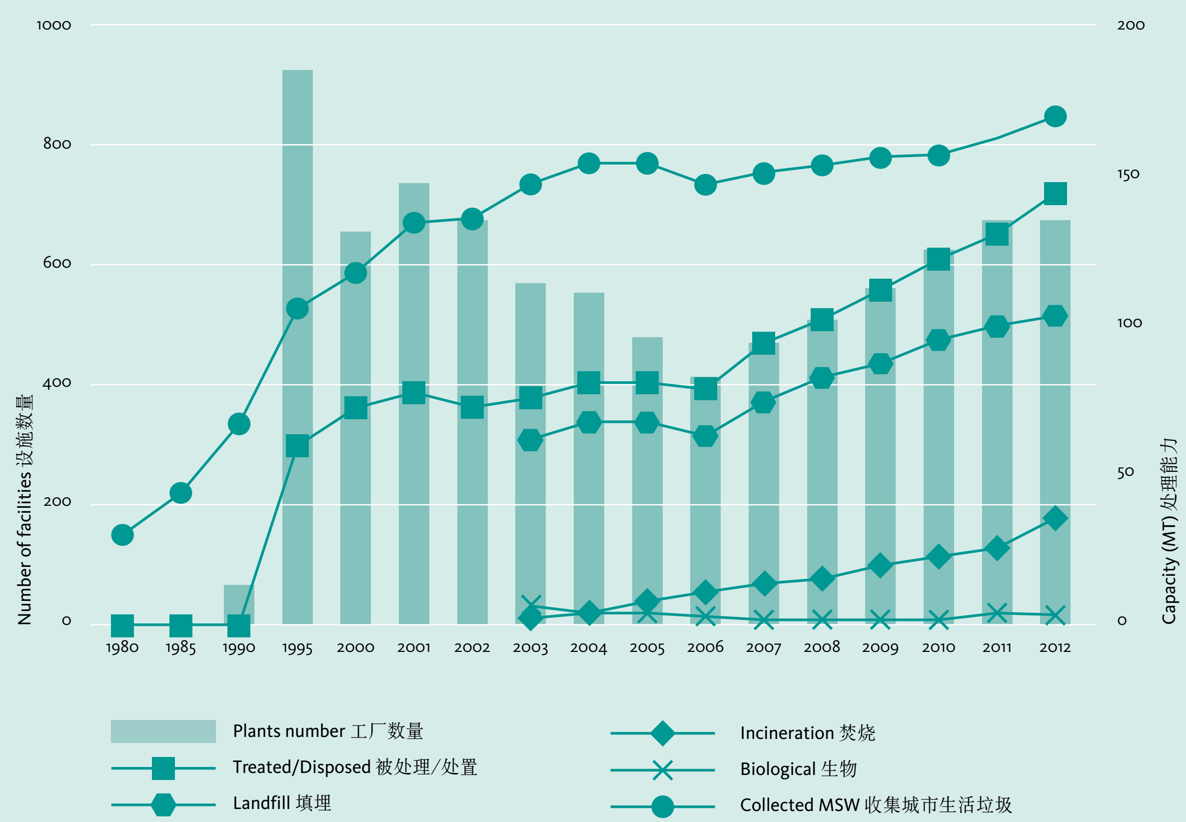
过去

中国的城市生活垃圾处理需求出现于1980年代。社会经济的发展，使城市生活垃圾的产生量增加，组分日趋复杂化。塑料等与土地不相容的组分开始出现在垃圾中，使垃圾不能直接在郊区的农田中施用。许多城市只能在荒地，甚至农田上堆置垃圾，出现了所谓的“垃圾围城”现象，对周边环境的影响非常严重。
面对城市生活垃圾处理的强烈需求，主要从经济成本方面考虑，中国政府提出了以填埋为主的城市生活垃圾处理技术政策（“国务院批准建设部等部门关于解决我国城市生活垃圾问题几点意见的通知”，[国务院]1992年7月4日），填埋成为中国城市生活垃圾处理的主流技术。中国生活垃圾处理量、无害化率、填埋处置能力和填埋场数量的演化过程见图1。
由图1可见，2000年前填埋处置的无害化水平并不高，主要的技术缺陷在于未采用符合标准（CJJ17-88城市生活垃圾卫生填埋技术标准）的防渗技术和渗滤液处理不达标（GB16889-1997生活垃圾填埋场污染控制标准）。（图1）

现在

2000年以后，中国颁布了与欧美发达国家相似的卫生填埋技术标准（CJJ17-2004生活垃圾卫生填埋技术规范），要求生活垃圾填埋场采用符合规范的复合防渗衬垫，并且颁布了严格的渗滤液处理排放限值（参见表1）。鼓励填埋气体的收集和利用。生活垃圾填埋的无害化水平由此得到了显著的提高。
目前，基于中国的特定条件，生活垃圾填埋已形成了一些特征性的技术。
_ GCL+HDPE复合防渗衬垫。中国主要人口聚居区缺乏低渗性（K<1.0 × 10-7cm/s）的黏土层。因此，HDPE（≥1.5mm）与GCL(≥8mm)复合的衬

Fig. 1: Collection and treatment of MSW in China (Reference: China Yearbook. 1980-2013)
图1: 中国城市生活垃圾的清运量和处理量
(参考文献: 中国统计年鉴, 1980-2013年)



垫，成为中国垃圾填埋场防渗的主流技术。
_采用PE膜材料作为日覆盖和中间覆盖材料。中国城市周边的土地利用密度极高，填埋场土层覆盖材料紧缺。填埋场以HDPE（0.5mm）或LDPE（1mm）进行中间的日覆盖，还相应发展了在膜覆盖层构筑车辆行驶通道的方法。
_生物—膜处理结合的渗滤液处理技术。中国生活垃圾填埋场的渗滤液产生率一般为0.2~0.3 m3/t填埋垃圾，即使是运行5年以上的填埋场，渗滤液COD也都超过10000 mg/L，达到排放限值需要的COD和TN去除率均高于99%。为此，中国生活垃圾填埋场的渗滤液处理流程较为复杂（参见图2）。因C/N比不利于处理要求，TN达标较为困难。

Composite GCL (geosynthetic clay liners) and HDPE (high density polyethylene) are widely used as in the major populated areas of China, there is a dearth of clay with low permeability ($K<1\times10^{-7}$ cm/s). Composite liners with an HDPE layer of more than 1.5 mm thickness and GCL layer of more than 8 mm are therefore popular as liners in Chinese landfill sites.
PE membranes are used as daily and intermediate covers. The land around urban areas of China is intensively used and there is consequently a shortage of soil for covering operations in landfill sites. As an alternative, HDPE with a thickness of 0.5 mm or LDPE (low density polyethylene) of 1 mm is used for daily and intermediate covers. Meanwhile, approach roads for truck access to the membrane cover layer need to be provided.
Leachate is treated by a combination of biological technology and membrane treatment. In Chinese MSW

Tab. 1: Limit values for the discharge of leachate (GB16889-2008)
表1: 现有和新建生活垃圾填埋场水污染物排放浓度限值 (GB16889-2008)

Pollutants 控制污染物	Limit value 排放浓度限值	Pollutants 控制污染物	Limit value 排放浓度限值
Apparent color (dilution ratio) 色度 (稀释倍数)	40	E.coli (number per Liter) 粪大肠菌群数 (个/L)	10000
CODcr (mg/L)	100	Hg (mg/L) 总汞 (mg/L)	0.001
BOD5 (mg/L)	30	Cd (mg/L) 总镉(mg/L)	0.01
SS (mg/L) 悬浮物 (mg/L)	30	Cr (mg/L) 总铬 (mg/L)	0.1
TN (mg/L) 总氮 (mg/L)	40	Cr (VI) (mg/L) 六价铬 (mg/L)	0.05
NH4+-N (mg/L) 氨氮 (mg/L)	25	As (mg/L) 总砷 (mg/L)	0.1
P (mg/L) 总磷 (mg/L)	3	Pb (mg/L) 总铅 (mg/L)	0.1

landfills, the generation of leachate can reach 0.2-0.3 m^3/t-waste. Even in a landfill being operated for more than 5 years, the leachate COD_{Cr} (chemical oxygen demand) can still exceed 10,000 mg/L. This means that the leachate treatment efficiency for COD or TN (total nitrogen) needs to be higher than 99% in order to comply with the standard requirement on leachate discharge. Hence, as shown in Figure 2, the leachate treatment process in Chinese MSW sanitary landfill is very complex. Owing to the unfavorable C/N (carbon to nitrogen)ratio, the standard TN index requirement is frequently hard to meet.

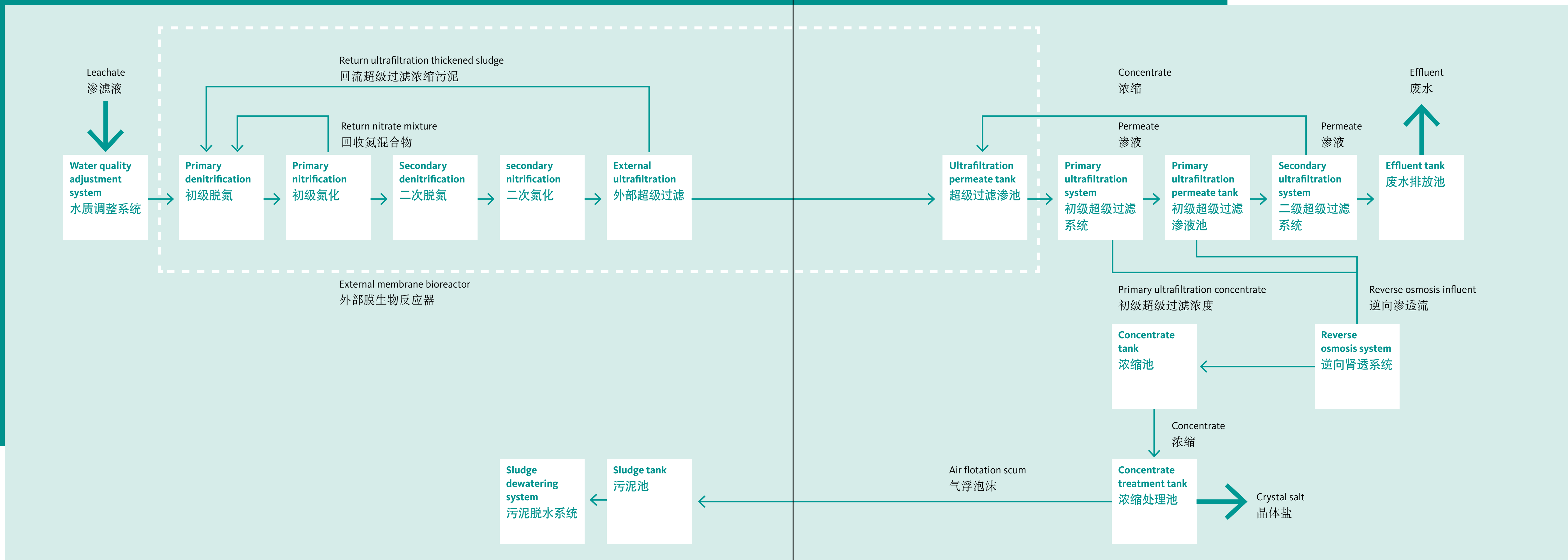
Future

Although landfilling remains the dominant technology for MSW treatment in China, its continued application is facing challenges. Firstly, the odor generated from landfill sites seriously impacts on the surrounding

未来

目前，尽管填埋仍是中国生活垃圾处理比例最高的方法，但填埋技术应用存在两方面的阻碍因素：1）填埋场臭气对周边环境影响范围较大，在人口密集区域选址困难；2）中国对焚烧发电上网实行“绿电”补贴，而填埋的污染控制要求又不断提升，填埋技术已失去对焚烧发电技术的成本优势。
中国国务院转发的“关于进一步加强城市生活垃圾处理工作的意见”（国发（2011）9号），及住房与城乡建设部编制的全国“十二五”生活垃圾处理规划，也均将焚烧发电技术列为优先发展的生活垃圾处理技术。

Fig. 2: Typical process for the treatment of landfill leachate in China
图2: 中国生活垃圾填埋场渗滤液典型处理流程



areas. As a result, it is difficult to find suitable land for landfilling in densely populated areas. Secondly, the economic stimulation of feed-in tariffs for waste-derived electricity promotes the development of incineration, while the pollution control costs cost of sanitary landfills are increasing, with the consequence that landfilling is no longer cost competitive with incineration. Furthermore, in recent years, all of the policy documents issued by China government have encouraged MSW incineration as a priority, e.g. the document 'On Further Strengthening the Work of Garbage Disposal' issued by the State Council (2011, no. 9), and the '12th National Five-year Plan on MSW Treatment' issued by the Ministry of Housing and Urban-Rural Development.

据此，在中国中东部主要人口聚居区，填埋技术作为原生生活垃圾的主要处理方法地位将逐步被焚烧发电技术所替代。未来填埋的功能将主要是作为焚烧灰渣的处置技术。将来填埋建设技术也许不会有大的变化，但操作方法及渗滤液收集处理等技术需要进行调整，以适应新的处置对象特征。

致谢：本研究得到“国家973重点基础研究发展计划课题”(2012CB719801)、“区域环境质量协同创新中心”和“高等学校创新引智计划”支持。

In the densely populated central and eastern areas of China, therefore, incineration is gradually substituting landfilling for the treatment of raw waste. In the future, the function of landfills will shift to becoming the disposal sites for incineration residues. There will be no significant change in landfill construction, but landfilling operations as well as collection and treatment of leachate will need to be adjusted, in order to adapt to the characteristics of new waste types.

Acknowledgement: The work was supported by National Basic Research Program of China (973 Program, No. 2012CB719801), the Collaborative Innovation Center for Regional Environmental Quality and 111 Project.

VIU training program echo from participants
威尼斯国际大学培训计划 学员回音

This section is written by the Chinese participants in the trainings in Italy. We hope hereby to provide the Newsletter readers with an authentic flavour of the training experience.

Chinese Academy of Social Sciences
Green Growth

Italy, March 16-27, 2014
39 participants

The Sino-Italian Cooperation Program's Green Growth training course in Eco-Management: Strategy and Advanced Policy Training was held from March 16-27, 2014. There were 39 participants attending the training course in Italy.
The organizers took as their starting point the basic concept of green development, and continued with a detailed introduction to the main initiatives and overall environmental protection policy accompanying the current industrial development of Italy and the European Union.
The training course concentrated on aspects of clean manufacture, waste management, energy efficiency, green food industry and green agriculture in Italy and the EU, and visited representative companies and factories.
All the training courses were built around the theme of green development, providing participants with a good overview of the relation between economic development and environmental protection in pursuit of a healthy ecological balance. Although different conditions prevail in China and Italy and the two countries are at different economic stages, Italy's ongoing ecological environment management experience and practical approaches prove to be well worth studying. As ecological environment problems are increasingly prominent in a rapidly developing China, establishing a sound conceptual framework in this area is an urgent priority.
Over an intensive and wide-ranging 12 days of study, the participants learned a great deal and would like to share the following experiences and suggestions:
First of all, participants generally think that green development is a very large topic, but the course time is limited. They regret that there was insufficient opportunity to discuss and focus on more specific aspects and hope in future to enhance the depth of the training in some of the more advanced ideas and technologies deployed in Italy's environmental protection program.
Secondly, the participants hope to continue to cooperate with Italy in strengthening environmental protection, and would like to see more Chinese professional and technical personnel attending this training program. They hope to further strengthen project cooperation in the fields of protecting the historical and cultural heritage, energy conservation, and environmental protection and urban planning in the context of urbanization, with the goal of optimizing the application of European technology to the Chinese market.

"学员回音" 由在意大利参加培训的中方学员们供稿的。希望通过刊登学员们的 "回音"，能够让 "培训园地" 的广大读者们多少有些 "身临其境" 的感受。

中国社会科学院
绿色发展

意大利，2014年3月16日-27日
39名学员

中意环保合作项目 "生态管理：战略与政策" 高级培训班于2014年3月16日-27日赴意大利开始了为期十二天 "绿色发展" 培训课程，共有39位学员参加了此次培训课程。
组织者从 "绿色发展" 的基本概念出发，对意大利和整个欧盟的工业发展和环境保护的主要工作和政策进行了详细的介绍。培训分主题从清洁生产、废弃物管理、能源效率、绿色食品工业和绿色农业等几个方面介绍了意大利和欧盟的情况，并对具有代表性的企业和工厂进行了参观、学习和考察。
本次培训所有的课程都围绕绿色发展的主题，为大家提供了一个很好的处理好经济发展与环境保护和生态平衡之间关系的范本。中意两国国情不同，经济所处的阶段也相异，但是意大利目前生态环境管理经验和实践模式值得我们学习借鉴。对于处于发展中且生态环境问题日益突出的中国而言，树立这方面的理念极为重要而迫切。
通过十二天全方位的学习，学员们收获颇丰并提出了以下体会和建议：
首先，学员们普遍认为 "绿色发展" 本身是一个比较大的主题，但课程时间较短，使得课程内容多是介绍性的泛泛而谈，无法对某一方面进行深入交流。建议今后的培训将主题再缩小一点，希望加强培训内容的深度，多介绍一些意大利方面先进的环保理念和技术。
其次，学员们都非常希望与意大利加强环保合作，也希望中国更多的专业技术人员能参加到这样的培训项目中。希望在中欧城镇化伙伴关系框架下，进一步加强与意方在历史文化保护、城市规划设计和节能环保方面的项目合作，实现欧洲技术与中国市场的完美结合。

Ministry of Science and Technology
High-Technology and Science Parks for Sustainable Development

Italy, June 21 – July 2, 2014
27 participants

Further strengthening Sino-Italian scientific and technological exchanges and cooperation in the field of sustainable development, the “China-Italy Training Course on Capacity-Building and Sustainable Development of High Technology and Technology Park” was a notable success. The delegation consisted of 25 experts and officials from relevant departments in Beijing, Shanghai, Heilongjiang, Zhejiang and other provinces in China, who visited Italy from June 21 to July 3, and successfully completed all the training assignments.

The training course combined classroom and field study. The topics varied from innovation and sustainable development within the framework of green technologies, to the strategic planning, legislation and technology policy of the European Union and Italy, to science and technology parks and high-tech development policies, to technological innovation and business incubators, and to human resource management. The lectures were delivered by more than 20 officials and experts from governments, research institutions and businesses. Basing themselves on the practical realities of their work, they explained the construction and management of science and technology parks, green innovation systems and the role of regional policy, combining case studies and site visits, helping the delegates to grasp the basic ideas, methods, specific implementation steps and measures taken by Italian enterprises in green technology innovation.

In the course of their trip, the group members were led to think in depth about the basic facts of China’s existing environmental management model, problems and possible measures for improvement. They also conducted comparative studies on policies and innovations in green and high technology. The training course provided a useful basis for their future work, promoting exchanges of ideas between policy-makers and experts in both countries, enhancing mutual understanding and laying a solid foundation for international cooperation in related fields.

Gao Yi
Chinese Academy of Science and Technology for Development

中国科学技术部
可持续发展的高新技术与科技园

意大利，2014年6月21日至7月2日
27名学员

为进一步加强中国与意大利在可持续发展领域的科技交流与合作，“中意高技术与科技园可持续发展能力建设”培训班于6月21日-7月3日成功举办。来自北京、上海、新疆、黑龙江、浙江、江西等地相关部门25名成员组成代表团，赴意接受培训，并圆满完成了培训任务。本次培训内容生动，课堂与实地结合。培训内容围绕绿色技术创新可持续发展主题，包括欧盟及意大利可持续发展领域的战略规划、立法和科技政策、高技术与科技园区发展政策、规划与生态建设、科技创新与企业孵化器、高技术人才与人力资源管理等。来自政府、研究机构和企业的官员、学者和技术专家20余人为团员们授课。所请专家学者从自身的工作实际出发，讲解了科技园区的建设和管理、绿色创新体系政策及区域性集中的作用等内容，并将专题讲座、政策讲解、案例分析与实地考察相结合。把授课内容和实地考察有机结合，使学员对意大利企业绿色技术创新可持续发展的基本思路、方法、具体的实施步骤、措施，既有理性的认知，又有感性的认识，既听又看，授课内容与实证案例相互印证，提高了对授课内容的理解，加快了消化吸收速度。

通过学习，团员们开阔了视野，拓宽了思路，对我国现行环境管理模式与技术现状、存在问题和改进方法有了深入的思考。不仅学习政策，更新观念，提高了绿色环保高新技术的政策理论水平和创新能力，而且开拓视野，增长见识，为今后开展相关工作提供了有益借鉴。最重要的是促进交流，增进了解，为加强国际合作研究奠定良好基础。

高懿
中国科学技术发展战略研究院

Air Quality Control, BMEPB and SEPB

Italy, June 8-18, 2014
41 participants

Air quality is surely a key topic today in China and, although Shanghai and Beijing face different situations, the two Municipalities were able to discuss positively together the importance of air monitoring and GHG, VOC, CO_2 emission control as well a whole range of issues related to air quality, in the search for new shared strategies and policies to be implemented for the benefit of their (respective) citizens.
To this end, also in 2014, BMEPB and SEPB jointly participated in the Advanced Training Program on Environmental Management and Sustainable Development founded by the Italian Ministry for the Environment, Land and Sea and organized by VIU. The first of two 2014 courses was focused on the theme of "Air Quality Control" and a delegation of 41 participants selected by the two Municipal Environmental Protection Bureaus spent 10 days in Rome, Venice and Turin.
The course was a mix of lecturing sessions about air quality legislation and policies, emission inventories, vehicle emission control, air pollution sources, permits for controlling pollution and sustainable mobility. These aspects were addressed both at the national and at the regional and local levels. Specific examples and concrete cases were the subject of many discussions and site visits to industries and power plants.

北京环保局和上海环保局培训项目
空气质量控制

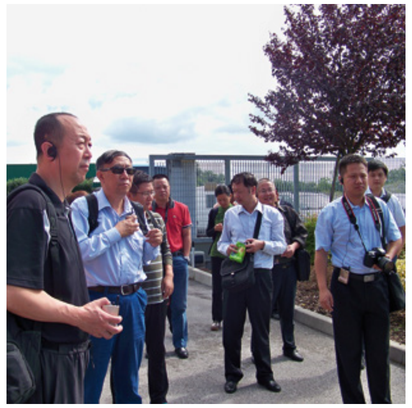
意大利，2014年6月8-18日
41位学员

改善空气质量是当前中国最重要环境保护任务之一。尽管北京和上海两市背景不同，但都面临空气污染问题，因此学员们非常希望能够围绕关于空气质量监测、削减和控制温室气体及挥发性有机物排放等议题进行研讨，并通过分享各自所制定的空气污染控制战略和政策来相互促进工作。
为此，在意大利环境部大力支持下，威尼斯国际大学为北京和上海市组织了“环境管理和可持续发展高级培训班”。一共有两期培训的主题为“空气质量控制”，两个城市共派出41名学员参加了第一期培训，历时10天，培训地点包括罗马、威尼斯和都灵。
培训班从国家、区域和地方层面围绕空气质量控制法规政策、污染物排放清单、机动车尾气控制、空气污染源、排放许可和可持续交通等方面进行讲解。通过组织现场参观企业和发电厂，让学员们对课堂讲授内容能够进一步理解，并可进行充分互动讨论。

Innovation of Enterprises and Green Technologies, MOST

Italy, September 6-17, 2014
27 participants

The Ministry of Science and Technology plays an important role in China's economic growth strategies by promoting many programs supporting innovation and new high technologies; progress in this direction also aims at improving people's living standards and creating a sound ecological environment in the country, by putting into practice the threefold approach that characterizes sustainable development.
In the light of this, the objective of the training course on "Innovation of Enterprises and Green Technologies" was to underline that when companies invest in innovative technologies for the protection of the environment they can also gain advantages from the economic point of view as they reduce wastage and use less raw material and energy.
The delegation that visited Italy between September 6 and 27 was composed of 27 participants selected from provincial science and technology departments and centers for technological innovation.
A few introductory lectures focused on the policies for the promotion of clean technologies in Italy and Life Cycle Assessment (LCA) technique, as a tool available to companies seeking to understand where they might take action to reduce their burden on the environment along the whole production cycle. Most of all, the participants were able to see for themselves many companies operating in very different sectors (energy production, mechanics, furniture, paper, boilers and steam engines, food), which share the objective of reducing the impact of the production processes or final products on the environment through the deployment or development of new innovative technologies.



中国科学技术部
企业创新和绿色技术

意大利，2014 年9月6-17,
27位学员

科技部在推动中国技术创新、实现经济增长方面发挥重要作用；同时技术创新对提高人民生活水平、改善生态环境质量具有重要意义，并将可持续发展的三个理念贯彻落实到实际工作中。
据此，将本期培训主题确定为“企业创新与绿色科技”，旨在强调企业为保护环境投入资金、减少废物产生、使用更少原材料，同时企业也应获得相应经济回报。
来自于中国各省科技厅和技术创新中心的代表共计27人，于9月6-27日访问了意大利。培训内容包括意大利促进清洁技术方面的相关政策、全过程减少对环境压力的生命周期评价工具(LCA)等等。此外还安排学员们参观了不同行业（包括能源、机械、家具、造纸、锅炉、食品加工等）先进企业，让学员们亲身感受到通过开发和利用技术创新，可实现从生产过程到最终产品逐步减少对环境造成压力的目标。

2014 has been a full year for the Advanced Training Program on Environmental Management and Sustainable Development and associated VIU initiatives. **13 training sessions**, over **450 participants** and more than **100 lecturers & speakers**: these are the figures for the 11th edition (2014) of the *Sino-Italian Sustainable Development and Environmental Management Advanced Training Program*. The participants travelled

between Rome, Venice and Turin visiting a variety of organizations and exchanging experiences and ideas with Italian experts on the priority issues for sustainable development in China.
Environmental Pollution Control has become established as one of China's main priorities, and the management of air pollution in particular represents a key issue in guaranteeing safety and general wellbeing. Furthermore, achieving an economy based on **Low Carbon Emissions and Green Innovation** is one of the main goals and challenges for China today.
1 Course for Sustainability for 21 high-level officials

回顾2014年《中意环境管理与可持续发展高级培训计划》及威尼斯国际大学开展的其他相关活动，可以说2014年对于威尼斯国际大学来说是充实而又忙碌的一年。
在《中意可持续发展与环境管理高级培训项目》第11个年头（2014年），**共举办13 期培训班，450名学员参加培训，100多名教授或培训老师应邀向学员们授课**。学员们访问了罗马、威尼斯和都灵，参观了一系列机构，并围绕中国推进可持续发展所面临的重点和优先问题，与意大利专家进行广泛交流。
环境污染控制已成为中国最优先工作之一，特别是空气污染管理涉及到人民安全与福祉。推动低碳发展、绿色创新是中国当今奋斗的主要目标之一。为东南欧国家21名环境部和地方政府高级别官员、东欧和北非14位代表等成功组织了**一期可持续发展培训班**。
与国际废物工作组（IWWG-2）合作开设了**2学期可持续废物管理课程**，学生包括来自8个国家的32名硕士和博士，20名国际知名教授优先保证为这些学生提供面对面指导和交流。废物管理教学课程所取得的巨大成功催生了明年开办废物管理国际学院的计划。
59名学生参加了威尼斯国际大学可持续发展全球课程，其中8名来自中国。这些课程从不同角度讲授可持续发展相关问题，让不同国籍、不同背景学生从各个层面接触这一复杂问题。
与我们的合作院校、外部单位、及私营企业密切合作，举办了**30 次研讨会和大会**，合作伙伴包括外交部、ENEL基金会、FEEM, the Coimbra Group, Alcantara等等。与各机构、不同利益方进行广泛合作，充分践行了威尼斯国际大学的使命，即：创造桥梁纽带，推动建立合作网络，并进行广泛交流对话。这些是实现可持续发展的关键要素。

from the Environmental Ministries and Municipal authorities of South-Eastern European countries, and 14 representatives from Middle East and North Africa MENA was concluded with great success.
2 Schools on **Sustainable Waste Management** were organized in collaboration with the IWWG-International Waste Working Group, involving 32 master and PhD students from 8 countries, who were given the opportunity to meet personally and learn from over 20 top-level international lecturers . From the success of these initiatives the idea has taken shape of establishing an International Academy on Waste Management which we hope to launch next year.
59 students attended the **VIU globalization courses on Sustainable Development**, 8 of whom were from China. These courses dealing with many different aspects of sustainable development, give students from different countries and backgrounds the opportunity to engage directly with this complex issue.
Over 30 workshops and conferences were also organized in collaboration not only with our partner universities, but also with external institutions and private companies. Just to mention a few, we can name the Italian Ministry of Foreign Affairs, the ENEL Foundation, ENI, FEEM, the Coimbra Group, Alcantara. The involvement of different stakeholders testifies to VIU's commitment to creating bridges between them and in promoting dialogue and networking, as key factors in achieving sustainable development.

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MINISTERO DELL'AMBIENTE
E DELLA TUTELA DEL TERRITORIO E DEL MARE

Venice
International
University

Venice International University
TEN Center, Thematic Environmental Networks
威尼斯国际大学
Isola di San Servolo
30100 Venice Italy
Tel. 电话 +39 041 2719525-524
Fax 传真 +39 041 2719510
ten@univiu.org

Italian Ministry for the Environment,
Land and Sea
意大利环境、领土与海洋部
Via Cristoforo Colombo, 44
00147 Rome Italy

Sino-Italian Cooperation Program
for Environmental Protection
中国－意大利环境保护合作项目管理办公室
Program Management Office, Beijing
北京项目管理办公室
4C Building, 6th floor
5 Hou Ying Fang Hu Tong Xin Cheng District,
100035 Beijing, P.R.China
中国北京市西城区后英房胡同5号
环保履约大楼6层
邮编：100035
Tel. 电话 0086-10-82268788
Fax 传真 0086-10-82200587/0586
newsletter@sicppmo.org
info@sicppmo.org
Program Management Office, Shanghai
上海项目管理办公室
Room 1901-1906,
The Center, 989, Changle Rd.
Shanghai, 200031 P.R. China
上海市长乐路989号世纪商贸广场1901-1906室
中意环保项目上海办公室
Tel. 电话 021 61104860
Fax 传真 021 61104861
info@sicppmo.org

AGRINNOVA