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Proceedings of the Regional Workshop  
**Wastewater Treatment and Reuse  
for Metropolitan Regions and Small Cities  
in Developing Countries**

Editor: Edmilson Santos de Lima

September 11-17, 2016 – Recife, Brazil



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Sustainable Water Management is essential for the social, economic, and environmental growth of developing countries. Many of those had very high population growth rates in the last century, resulted in fast urbanization and strengthened by heavy migration from rural areas to the cities either of big or small size. Water supply of good quality and adequate quantity, especially in countries with semi-arid regions, and appropriate sewerage systems and treatment of wastewaters impaired severe constraints for the population. Nevertheless, many alternatives for wastewater treatment were developed with the participation of universities and research institutions as well as by practitioners. Substantial efforts have been directed towards the search of good alternatives for domestic sewage treatment in metropolitan regions and small cities in developing countries in order to comply with their particular economic and environmental conditions. The use of conventional treatment technologies as well as advanced alternatives for treatment and post-treatment of wastewater, issues of plant scales in centralized and decentralized systems, and possible reuse of the effluents were aimed to present on this workshop and to discuss theoretical and practical aspects.

The main objectives of the workshop were (i) to share experiences, knowledge, and research between different partners; (ii) to discuss major problems and challenges in the field of wastewater treatment and reuse in Metropolitan Regions and Small Cities in Developing Countries; (iii) to present suitable treatment technologies for domestic wastewater for the removal of recalcitrant substances and micro-pollutants from domestic sewage and industrial effluents; and (iv) likeliness of reuse of treated wastewater in urban areas, in the industry, and in agriculture. Individual topics dealt with were (v) alternatives for domestic sewage treatment in metropolitan regions and small cities; (vi) anaerobic processes for the treatment of domestic sewage and industrial wastewaters; (vii) stabilization ponds; (viii) aerobic granular sludge; (ix) post-treatment processes; (x) centralized and decentralized systems; and (xi) water reuse.

Editor  
Prof. Dr. Edmilson Santos de Lima



Proceedings of the Regional Workshop

# Wastewater Treatment and Reuse for Metropolitan Regions and Small Cities in Developing Countries

Edmilson Santos de Lima

September 11-17, 2016 – Recife, Brazil

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## CONTENT

Preface .....	1
Natural wastewater treatment and water quality monitoring system for effective reuse ( <i>S.E. Abbenante, M.D. Vergara</i> ) .....	2
Selection of plant species used in wastewater treatment ( <i>E.S. Vogelmann, G.O. Awe, J. Prevedello</i> ) .....	9
Assessing environmental impacts of wastewater treatment alternatives for small scale communities ( <i>M. Yildirim, B. Topkaya</i> ) .....	19
Evaluation of decentralized approaches to wastewater treatment systems as alternative to environmental impacts and indication of sustainable solution for water conservation in cities ( <i>M.C. Chispim</i> ) .....	28
Comparative reliability analysis for effluent quality of centralized and decentralized wastewater treatment plants ( <i>J.C. Morais, E. Pastich, R.J. Silva, S. Gavazza, L. Florencio, M.T. Kato</i> ) .....	38
Single and two phase thermophilic anaerobic digestion of waste activated sludge: Performance and energy assessment ( <i>W. Leite, M. Gottardo, P. Pavan, P.B. Filho, D. Bolzonella</i> ) .....	48
Interval approaches for optimization and control of wastewater treatment processes by anaerobic digestion ( <i>V. Alcaraz-Gonzalez, V.G. Alvarez</i> ) .....	58
Sorption of phenol/tyrosol from nanofiltrate stream stream of a pretreated olive mill wastewater using a macro-reticular aromatic polymeric resin ( <i>J.R. Njimou, M. Stoller, A. Cicci, A. Chianese, C.P. Nansau-Njiki, E. Ngameni, M. Bravi</i> ) .....	68
Catalyzing Fenton reaction for dyeing color disposal by using uncoated-pottery scraps (UPS) ( <i>S. Muangthong, N. Supamathanon</i> ) .....	78
Acrylamide degradation by direct photolysis (UV) and conjugated photolysis (UV/H <sub>2</sub> O <sub>2</sub> ) ( <i>E. Carissimi, J. Martini, S.C. Zilli, T.M. Pizzolato</i> ) .....	86
Circular economy: A new perspective for the O&G industry in Brazil ( <i>J.T. Araruna Jr., P.J.M. Pires, R.C. Vaqueiro, P.M.B. Manhaes</i> ) .....	94
Reuse of wastewater for irrigation in MENA region and Konya experiences ( <i>M.E. Aydin, S. Aydin, F. Bedük, M. Bahadir</i> ) .....	104
Greywater reuse in Jordan – Community-based experiences ( <i>A.O. Alulayyan, H.A. Ababneh</i> ) .....	113
Climate protection through sustainable waste management ( <i>C. Pereira, K. Fricke, J. Giersdorf</i> ) .....	122

## **PREFACE**

This proceedings book brings 14 papers selected out of 27 presented at the International Expert Workshop on “*Wastewater Treatment and Reuse in Metropolitan Regions and Small Cities in Developing Countries*”, held in Recife, Brazil September 14–16, 2016 within the framework of the EXCEED SWINDON Project. Participants were from 9 different countries (Argentina, Brazil, Cameroon, Colombia, Germany, Jordan, Mexico, Thailand and Turkey) that made the workshop very broad in participation and expertise.

The main objectives of the workshop were to share experiences, knowledge, and research outcomes between the different participants, and to discuss the main problems and challenges in the field of wastewater treatment and reuse for Metropolitan Regions and Small Cities in Developing Countries. In addition, the workshop dealt with suitable technologies for domestic sewage treatment, removal of recalcitrant substances and micro-pollutants from domestic sewage and industrial wastewater, and reuse of treated wastewater in urban areas, industry and agriculture. Another important goal of the workshop was to further strengthen the expert network within the EXCEED SWINDON Project.

Two independent experts, Prof. Dr. Lourdinha Florencio and Prof. Dr. Mario T. Kato reviewed all papers submitted to the workshop in terms of their scientific content, and the Publishing Editor of the Proceedings Book, Prof. Dr. Müfit Bahadır made the final publishing review. As the Issue Editor of these proceedings I cordially acknowledge their invaluable contributions while publishing this book.

I hope and am confident that the readers will gain benefit from reading these papers.

Prof. Dr. Edmilson S. de Lima  
Centro de Tecnologia e Geociências, Universidade Federal de Pernambuco, Brazil

# NATURAL WASTEWATER TREATMENT AND WATER QUALITY MONITORING SYSTEM FOR EFFECTIVE REUSE

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**Keywords:** Argentina, Phytoremediation, Wastewater treatment, Wetlands, Software monitoring

## **Abstract**

There is a large quantity of wastewater in Argentina, of which only about 10% is treated to reuse. The rest is sent directly to the rivers without any treatment, which increase their pollution. It is estimated that 73% of water in rural areas of Argentina is used for agriculture and livestock. An investigation concluded that there are few efficient methods in rural areas of Argentina to mitigate this problem. The solutions that have been proposed are too expensive to be applied in these areas. For this reason, the works are not completed because of high cost of investment and maintenance. From these findings, an easy handling and low cost investment tool of wastewater treatment as well as a system designed with “free software” tools to control and to monitor its quality was developed as a solution of this problem and to extend it elsewhere in the world with similar needs. First, the characteristics of design and implementation of wastewater treatment plant in rural areas through wetlands using native plants are presented in this study, and the details of this technique are explained. Then a solution to monitor and to optimize the water quality through software for their effective reuse is presented. Finally, the application of the two techniques and the performance, when both methods are applied, are presented in a scenario. This study has shown that by applying these techniques the treatment area will gain benefits from using low cost implementation tools, easy handling techniques and optimization of processes.

## SELECTION OF PLANT SPECIES USED IN WASTEWATER TREATMENT

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**Keywords:** biological treatment; constructed wetlands; plant species; water quality; waste treatment.

### Abstract

The treatment of effluents using biological methods such as plants is a complex waste management option comprising water, substrate, plant roots, and a large number of microorganisms which interrelate. A major advantage of this system is that it can be implemented *in situ* where the effluent is produced, with low cost of operation, low energy consumption and operational simplicity. The treatment is basically using plants to utilize nutrients contained in the effluent and convert to green mass, in other words the plants acting as extractors of macro- and micro-nutrients in the effluent material. In addition, such plants may also extract or permit the possibility of transforming materials containing heavy metals and toxic organic compounds that may appear difficult to treat. However, in order to succeed in such treatment option, a selection of plants should first be carried out, which is based on some criteria such as: (i) good natural adaptation to the local climate; (ii) rapid growth and high biomass production; (iii) nutrient absorption capacity; (iv) adaptation and ease of propagation; (v) good root development; (vi) oxygen transfer capacity to the roots by creating aerobic environment. However, due to the great diversity of flora, further research is needed in relation to the evaluation and selection of plant species having potentials for use in wastewater treatment in constructed wetlands.



# ASSESSING ENVIRONMENTAL IMPACTS OF WASTEWATER TREATMENT ALTERNATIVES FOR SMALL SCALE COMMUNITIES

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**Keywords:** Constructed wetland, land treatment, LCA, stabilization pond, wastewater treatment.

## Abstract

The effluents of wastewater treatment plants from small sized communities of less than 2000 population equivalents (p.e.), which are discharged into sensitive receiving water environments, must receive “appropriate treatment” according to the EU Urban Wastewater Treatment Directive. Appropriate treatment depends on the quality objectives of the receiving waters as well as the relevant provisions of the member states. In this study, wastewater treatment options, such as vegetated land treatment (VLT), constructed wetlands (CW), stabilization ponds (SP) and activated sludge treatment (AST), by which effluents are discharged to sensitive and less sensitive areas are evaluated by the life cycle assessment (LCA) approach. For this purpose, data related to energy usage, land requirement, raw material consumption, and released emissions from the life phases were collected with an inventory study and the environmental impacts were assessed by using SimaPro 7.1 LCA software. The results obtained from the assessments were compared with each other, which indicated that for small scale communities Vegetated Land Treatment and Constructed Wetlands are the most environmentally friendly wastewater treatment options.

# EVALUATION OF DECENTRALIZED APPROACHES TO WASTEWATER TREATMENT SYSTEMS AS ALTERNATIVE TO ENVIRONMENTAL IMPACTS AND INDICATION OF SUSTAINABLE SOLUTION FOR WATER CONSERVATION IN CITIES

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**Keywords:** Nutrients, Reuse, Sanitation, Sustainability, Water

## **Abstract**

The Millennium Development Goals aim to achieve the sustainable development and to contribute improving access to water supply, sanitation, and energy, and to reduce hunger in the world. Energy and water are essential resources for food production, however, are becoming scarce. In this context an integration of the complete water management cycle includes water conservation and reclamation, storage of reclaimed water and rainwater, and wastewater treatment mainly in decentralized models. Wastewater treatment systems can generate products such as: renewable energy, fertilizers and water. This study focuses on the relations between wastewater treatment systems and its environmental impacts, besides to indicate potential solutions. In addition, it is also presented results from an experimental greywater treatment system operated at the university. The objective of this study was to address some Brazilian experiences of centralized wastewater treatment plant (large scale) and decentralized wastewater treatment plant (small scale). We expect that the results of this study can offer a review of strategies of wastewater treatment to implement in urban areas in Brazil, and to create subsidies for the planning of new wastewater treatment plants with low environmental impacts, including sustainable solutions (e.g., water reuse).

# COMPARATIVE RELIABILITY ANALYSIS FOR EFFLUENT QUALITY OF CENTRALIZED AND DECENTRALIZED WASTEWATER TREATMENT PLANTS

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**Keywords:** Activated sludge, domestic sewage, ponds, stone filters, UASB reactor

## Abstract

This study of reliability analysis was based on the effluent data of four wastewater treatment plants (WWTPs) with different treatment technologies. The effluent constituents considered were: total COD, filtered COD, TSS, N-NH<sub>4</sub> and *Escherichia coli*. The centralized Janga WWTP (activated sludge) obtained reliability levels of 85, 80, 90 and 70% for total COD, filtered COD, TSS and N-NH<sub>4</sub>, respectively. The decentralized Mangueira WWTP (UASB reactor + polishing pond) presented reliability levels of 40, 80, 40 and 85% for total COD, filtered COD, TSS and N-NH<sub>4</sub>, respectively. In the decentralized Rio Formoso WWTP (UASB reactor + polishing pond + stone filter), it was observed an increase in the level of reliability which was attributed to the stone filters; the reliability levels were 70, 90, 85 and 85% for total COD, filtered COD, TSS and N-NH<sub>4</sub>, respectively. Additionally, there was an excellent *E. coli* reliability level of 99%. The decentralized Petrolândia WWTP (facultative + 2 maturation ponds) obtained 60, 70, 70 and 30% for total COD, filtered COD, N-NH<sub>4</sub> and *E. coli* reliability level, respectively. The contribution of this reliability study consisted in generating data, which can be used by designer/operators in the performance evaluation of other WWTPs, considering the quality of the effluent.

# SINGLE AND TWO PHASE THERMOPHILIC ANAEROBIC DIGESTION OF WASTE ACTIVATED SLUDGE: PERFORMANCE AND ENERGY ASSESSMENT

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**Keywords:** Anaerobic digestion, single-phase reactor, thermophilic, two-phase reactor, waste activated sludge

## Abstract

Single and 2-phase anaerobic digesters were conducted at the same conditions of organic loading and retention time in order to compare their performances on sludge stabilizing and biogas yields. There was a slight increase in terms of volatile solids' removal, rising from 34% in the single-phase system to 38% in the 2-phase system. As a consequence, its global specific biogas production was greater around  $0.31 \text{ m}^3/\text{kg TVS}_{\text{fed}} \times \text{d}$ . The 2-phase system produced 15% more energy than the single stage system. Furthermore, the positive energy balance developed for both systems depicted none costs with external energy for sludge heating purposes. The estimated payback period to recovery the investment of the realization of the hydrolytic reactor was about 3 years.

# INTERVAL APPROACHES FOR THE OPTIMIZATION AND CONTROL OF WASTEWATER TREATMENT PROCESSES BY ANAEROBIC DIGESTION

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**Keywords:** Anaerobic Digestion, Interval Observers, Process Control, Robustness, Wastewater Treatment.

## **Abstract**

Several approaches for the modeling, optimization and process control of anaerobic digestion for the treatment of municipal and agricultural wastewater are reviewed in this paper. In particular, anaerobic digestion is presented as study case for these approaches. Anaerobic digestion is known for showing instability under certain conditions. In this paper, at least one suitable approach is presented for dealing with some of these drawbacks in particular and for optimizing the whole process.

# SORPTION OF PHENOL/TYROSOL FROM NANOFILTRATE STREAM OF A PRETREATED OLIVE MILL WASTEWATER USING A MACRO-RETICULAR AROMATIC POLYMERIC RESIN

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**Keywords:** equilibrium, fixed-bed, macro-reticular aromatic, nanofiltrate, phenol/tyrosol

## Abstract

Phenol and tyrosol are two phenolic compounds found in the effluents from olive mill waste waters (OMWW). Owing to its toxicity and its reactivity, phenol is slightly acidic, soluble in water. Likewise, tyrosol together with hydroxytyrosol belongs to the group of antioxidants contained in OMWW and deserves a close attention for the pharmaceutical, cosmetic and food industries. Polyphenol compounds, lipid and organic acid may be transformed into phytotoxic materials. This is the reason why the disposal of the OMWW into agricultural ground, usually adopted in the Mediterranean countries, cannot be adopted any more. In the current work, the concentrate of nanofiltration containing the low-molecular-weight compounds of the waste occurring from a membrane process was used for further treatment with R&H FPX66 aromatic resin. The operating parameters affecting the adsorption in batch mode process were studied and phenol adsorption was found to be larger than that of tyrosol. Equilibrium data was properly fitted by a pseudo-second-order rate fitting equation. The non-ionic FPX66 resin was implemented in a fixed bed column, for the recovery of phenols and their separation from compounds of interest.

# CATALYZING FENTON REACTION FOR DYEING COLOR DISPOSAL BY USING UNCOATED-POTTERY SCRAPS (UPS)

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**Keywords:** Fenton oxidation, Heterogeneous catalyst, Nakhon Ratchasima Province, Thailand

## Abstract

Textile is very famous and it is one of the major industries in Thailand. Each year, dye factories use a lot of dye and release it into the natural water resources such as Pakhongchai's silk village, Nakhon Ratchasima Province, Thailand. The dye components cause water pollution and they are hardly subject to degradation as recalcitrant chemicals. One way to remove Methyl Orange (MO) in dye adsorption process is using zeolite adsorbents. The pottery industry is famous and important like the textile industry in Thailand. Waste products from Dankwian's pottery village, Nakhon Ratchasima Province, Thailand, have a lot of Clayton-iron used for the adsorption process of dye wastewater treatment. This study used the component of clayton-iron for dye adsorption process to treat dyeing water. The experimentally obtained results show that the defects of uncoated pottery are capable of catalyzing the Fenton process. At the best conditions (at 60 mg/L methyl orange, 50 mL of the wastewater, 10 mg/L pottery scraps, 10 mM hydrogen peroxide, pH 3, and 90 min reaction time at room temperature, the methyl orange disposal efficiency reached 90%.

# ACRYLAMIDE DEGRADATION BY DIRECT PHOTOLYSIS (UV) AND CONJUGATED PHOTOLYSIS (UV/H<sub>2</sub>O<sub>2</sub>)

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**Keywords:** acrylamide; advanced oxidation process; degradation kinetics; HPLC; UV light

## Abstract

Acrylamide (AA) is widely used in the production of polyacrylamide, which is used as a polymer for drinking water clarification and wastewater treatment. The use as a polymer is the main source of contamination of acrylamide in water for human consumption. WHO established a maximum of 0.5 µg/L residual level due its carcinogenic effects. Thus, the main goal of this work was to investigate the efficiency of UV and UV/H<sub>2</sub>O<sub>2</sub> processes for the acrylamide degradation in aqueous solution. The experiments were carried out in a batch quartz photo reactor with a mercury vapor lamp inside a timber box to block radiation. Direct UV photolysis experiments were carried out (10 min interval of sampling) and UV/H<sub>2</sub>O<sub>2</sub> conjugated photolysis (5 min interval of sampling). Monitoring of acrylamide degradation was carried out with a HPLC-UV. Results showed that AA has been degraded when employed UV and UV/H<sub>2</sub>O<sub>2</sub> photolysis systems. The UV/H<sub>2</sub>O<sub>2</sub> process resulted in 89% reduction in AA concentration almost instantaneously in less than 2 min, probably due to the generation of large amounts of hydroxyl radicals, since these are generated when H<sub>2</sub>O<sub>2</sub> is exposed to UV. The use of UV radiation also resulted in a complete degradation of AA, but with a 360 min exposure.



# CIRCULAR ECONOMY

## A NEW PERSPECTIVE FOR THE O&G INDUSTRY IN BRAZIL

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**Keywords:** brick manufacturing, circular economy, drilling cuttings, hazardous wastes

### **Abstract**

This paper presents an innovative treatment technique for drilling cuttings, one of the most complex wastes of the oil industry. This treatment applies the concept of circular economy as it employs key parameters of its philosophy: the use of innovation through research of new materials employing recoverable resources by industrial symbioses. The treatment process involves the incorporation of drilling cuttings, up to 10% in weight, to the resulting mass used for manufacturing bricks. It consists of applying high temperatures, over 800 °C, to the resulting mass in order to obtain a solid, resistant and non-hazardous material. In addition, its strength is higher than those from bricks made only by clayey mass. Its technological parameters (i.e., porosity, water absorption and unit weight) also show better values to those bricks made only with clayey materials. As a result, an environmental permit is issued by the State of Bahia Environmental Agency. So far, three independent brick making industries are now adding drilling cuttings to their process.

## REUSE OF WASTEWATER FOR IRRIGATION IN MENA REGION AND KONYA EXPERIENCES

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**Keywords:** Irrigation, soil pollution, water scarcity, wastewater treatment, water reuse

### **Abstract**

Arid and semiarid regions receive very little precipitation; therefore, water sources are limited. However, water demand is very high because of high temperature and population. Over 80% of water demand is for agricultural use in Asia and Africa. Due to the urbanization and industrialization of rural areas, the demand for water resources has grown and water becomes increasingly polluted. Wastewater reuse appears to be an available source for irrigation purposes and being practiced in several parts of the world. In this work, general information about water supply, wastewater treatment, effluent discharge and reuse applications in MENA Region as well as in Turkey are exemplified. An overview is given about the wastewater reuse in particular for irrigation purposes in Turkey and the Arab Countries in the Middle East. Annual Mean precipitation amount in Konya is about 325 mm. Surface area of Konya is about 63,757 km<sup>2</sup>, which is about 8% of Turkey's total surface area. The amount of land suitable for agriculture is 2,754,243 ha in Konya, while about 835,000 ha of this land could be irrigated at present. Therefore, irrigation water demand is very high. Water usage, wastewater treatment and reuse practices, and experiences of Konya are presented. Some results of a scientific project carried out on pollution caused by long term irrigation with wastewater in the agricultural area of Konya are presented, as well.

## GREYWATER REUSE IN JORDAN – COMMUNITY–BASED EXPERIENCES

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**Keywords:** Agriculture, Greywater, Jordan, Reuse, Treatment.

### **Abstract**

Recently, the crisis of water shortage in Jordan has been exacerbated by the climate change, high population growth, frequent influxes of refugees, increased rural to urban migration, and modernization with higher standards of living. Consequently, Jordan is facing a future of very limited water share among the lowest in the world on a per capita basis. This paper describes the possibilities and opportunities of reusing the greywater as a nontraditional water resource for agricultural uses through a pilot project in Mafraq, Jordan. 10 Greywater treatment units were installed in 10 houses. These treatment units were designed according to the quantity and quality of the greywater. The quality of treated greywater varied from sample to sample. The pH varied from 7.41 to 8.93, BOD<sub>5</sub> from 258 to 474 mg/L, TSS from 10 to 256 mg/L, TP from 2.90 to 10.4 mg/L, NH<sub>4</sub> from 49.7 to 414 mg/L, *E. coli* from 3x10<sup>3</sup> to 2.8x10<sup>6</sup> MPN/100 mL, and fecal *Enterococcus* from <2 to 2.4x10<sup>2</sup> MPN/100 mL in the tested samples. In this paper, a case study has been conducted and reported in order to assess the economic and social impacts of reusing greywater. The study revealed that greywater reuse is feasible under specific conditions.

# CLIMATE PROTECTION THROUGH SUSTAINABLE WASTE MANAGEMENT

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**Keywords:** Capacity building, climate change, know-how transfer, waste management

## Abstract

In 2010, the National Solid Waste Policy (PNRS) of Brazil was issued, which is based on principles concerning sustainable solutions for problems associated with waste management, resources preservation and climate protection. Therefore, the PNRS creates a positive agenda for the encouragement of adaptation of landfills as electric power plants; closing and remediating wild dumps and promoting waste valorization, recycling and social inclusion. All these new proposals should face the Brazilian reality that goes from economic feasibility discussion over the lack of knowledge to implement sustainable solutions. This fact is not due to lower market interest in the subject, but rather due to the pioneering condition, with no large-scale examples that give opportunity for experiences' exchange. Furthermore, the importance of waste management for greenhouse gas (GHG) emissions and the availability of climate protection measures are hardly known. Based on this need, the proposed international climate initiative (IKI) project aroused a lot of attention in the market, resulting in the formation of strategic and multidisciplinary partnerships for the purpose of democratization of data as well as the development of joint projects that minimized errors, and optimizing the arrangements in favor of consistent projects. The results are still modest but encourage an innovative approach based on integration of consolidated market with new and great opportunities in Brazil.