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The roles of cleaner production in the sustainable development of modern societies: an introduction to this special issue

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ABSTRACT

This issue of the *Journal of Cleaner Production* is based upon papers presented at the **1st International Workshop Advances in Cleaner Production (CP)** held in São Paulo, Brazil, in 2007. The conference had the short-term purpose of deepening the Brazilian discussion on "*The Roles of Cleaner Production in the Sustainable Development of Modern Societies*", and it had the long-term objective of providing an on-going interdisciplinary forum for knowledge development and exchange on Cleaner Production (CP) and Sustainable Development. This issue is devoted to papers covering a broad range of perspectives of CP practices and strategies. A special focus is placed upon methodological tools designed to support effective decision-making pertaining to quantitative benefits from CP.

The ten papers provide insights from research designed to holistically integrate CP to help society make effective progress to sustainability. Papers cover the importance of informal knowledge, as complementary to formal knowledge, in performing effective 'Environmental Impact Assessments.' One paper explores the roles of radical and incremental innovation in the context of alternative automotive technologies. Benefits of Ecodesign are explored in two papers; one concerning its integration with remanufacturing to extend the life of used products and one focusing the adoption of 'Emergy Environmental Accounting,' as a complementary decision-making tool. The development of the Brazilian LCI database for 'hydroelectric power generation' and its contribution to support regionally relevant LCA studies is highlighted in one paper. The complete production chains of biodiesel and bioethanol are evaluated by using global methodologies, which help in the development of more objective and effective solutions. A "compensatory area", calculated in terms of emergy, is proposed in order to work in a sustainable way for bamboo production. Finally, a paper about a novel approach for recycling used PET is also included.

1. Introduction

When Prof. Donald Huisingh, Editor-in-Chief of the Journal of Cleaner Production (JCLP) and the main lecturer at the **1st International Workshop Advances in Cleaner Production**, offered us the possibility of making the conference papers available to a global audience via a special issue (SI) of the JCLP, we immediately accepted that opportunity, since publication of a SI issue would not only be coupled with, but would also reinforce our efforts to fulfill our conference objectives: Increasing academic information exchange on CP, presenting results of recent achievements in CP, sharing of knowledge among people from developed and emerging economies, discussion of common problems and solutions, and helping to establish this conference as a recognized forum for on-going dialogue on CP and Sustainable Societal Development.

This first conference was very successful, with participants from one hundred and eleven universities and colleges from Brazil, and other Latin American countries as well as from countries throughout the world. Seventy-five academic contributions were presented; they and the related debate helped to plant the seeds for achieving our long-term objective, to become a forum for on-going academic information exchange.

The objective of facilitating presentations and discussions of recent achievements in CP was also attained by means of participation of public companies and the industrial sector. Seventeen industrial and twelve plenary sessions reporting on institutional CP successes were key elements of the conference. The conference provided opportunities for exchange between academic knowledge and corporate experiences (63 companies in the industrial sector

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and 51 public sector companies sent participants to the conference).

2. The roles of cleaner production in the sustainable development of modern societies

The objective of discussing the roles of CP in the sustainable development of modern societies in a specialized forum was the central challenge for the participants at the **1st International Workshop: Advances in Cleaner Production,** hosted by Paulista University of São Paulo, Brazil.

Sustainable development, due to its philosophical and multi-disciplinary and long-term horizons, requires a new set of visions, paradigms, policies, methodological tools and applicable procedures to be developed, tested and widely applied, IF WE ARE TO MAKE THE URGENTLY NEEDED CHANGES FROM UNSUSTAINABLE TO SUSTAINABLE SOCIETAL PATTERNS.

In order to accomplish the necessary changes, we must integrate the academic results and insights with practical applications in society, at large. Based upon those sets of experiences, we will be better able to transform concepts and principles into a more sustainable and dynamic societal framework and process.

The complexity of the process of making the necessary changes to SD often impedes academics, governmental leaders and industrialists from proceeding beyond describing the dimensions of the challenges. Consequently, little progress has been made in resolving short and long-term social, environmental and economic dimensions. The increasing severity and frequency of consequences of 'climate change' underscores both the complexity and the urgency that we learn to increasingly effectively work on developing, testing and implementing, multi-disciplinary strategies to make progress toward sustainable societies.

The challenge is not easy since every dimension to be dealt with, has its own particularities that will have to be accessed from a holistic point of view in order to integrate the parts and to achieve positive and permanent results. Complementarily, we must be fully aware that each dimension must be thoroughly researched and the solutions must be scientifically verified. Having stated this, we are also fully aware that the social and psychological dimensions of human behavior are not fully within the logical, scientific domain, therefore, stakeholder involvement and empowerment are essential in seeking to gain consensus on the alternative pathways toward more equitable and sustainable societies.

The team, which assembled this special issue, is fully aware that no single issue can address ALL RELEVANT dimensions of SD, but rather it can seek to catalyze a deeper understanding of the possible roles CP can play in SD.

It is known [1] that cleaner technologies and CP, are in general, diffusing comparatively slowly, in spite of the great benefits that have been documented in systems where they have been implemented. Complementarily, it is argued that [2] implementation of CP programs is, in itself, no guarantee of continuity in environmental progress unless management systems are used in order to make the activities continuous and systematic on the journey of improvement. In this way, the necessity for decision makers to develop and implement proactive, integrated policies and strategies for helping societies to manage all resources in more sustainable ways is urgent [3].

The transition to more sustainable societies is closely tied to the following environmentally ***relevant aspects***: a. more efficient and conscious usage of raw materials; b. more efficient and conscious usage of non-renewable and renewable energy sources and energy technologies; c. reduced emissions and impacts; d. expanded implementation of closed-loop systems of materials, both intra and inter companies (end-of-life strategies promotion); and e. accelerated integration of renewable sources to as many processes as possible.

The adoption of environmentally sound technological solutions based upon scientific research and societal testing is another relevant emphasis that should be addressed. Fortunately, this is being increasingly done by some companies via implementation of environmentally-oriented, socially responsible economically sound, management programs; such approaches provide the benefit of helping them to simultaneously make environmental, social and economic progress. This win-win-win approach is sometimes called the Triple Bottom Line (TBL).

Within this conference, thoroughly documented and tested tools as well as, until now, industrial interventions that were not so widely known, have been used to guide work towards achieving environmental quality improvements and economic benefits at the same time.

However, we also addressed the crucial roles of governmental rules and regulations to serve as the framework, and the catalyst for company leaders to move forward. Of course, clear and uniform timetables for implementation combined with monitoring and enforcement are co-essential for achieving the environmental goals.

Each of these elements is integral to the CP approach; each is explored in one or more of the articles of this special issue. The collection of keywords confirms this point.

3. CP relevant aspects addressed in this special issue

A brief overview of the keywords chosen by the authors of the ten papers of this special issue provides an outline of the topics addressed. In order to properly confirm the consistency among the themes of the conference and the content of this special issue, a comparison was made between the keywords and the relevant CP approaches, which can contribute to helping societies to make the transition to more sustainable societies.

3.1. Efficient and conscious usage of raw materials: PET recycling (keyword found in ref. [13]), materials selection (in ref. [7]).

3.2. Efficient and conscious usage of energy sources and energy technologies: Fuel Ethanol *(bio-ethanol)* (in ref. [10]), Ethanol *(bio-ethanol)* (in refs. [5,11]), Biodiesel (in ref. [9]), Biofuels (in refs. [5,11]), Hydropower (in ref. [8]) and Hydroelectricity (in ref. [8]).

3.3. Reduced emissions and impacts: PET recycling (in ref. [13]), Ecodesign (in refs. [6,7]), "End-of-life" approaches (in ref. [6]).

3.4. Implementation of closed-loop systems for materials: PET recycling (in ref. [13]), Remanufacturing (in ref. [6]), "End-of-life" approaches (in ref. [6]).

3.5. Integration of renewable sources to the processes: Fuel Ethanol *(bio-ethanol)* (in ref. [10]), Ethanol *(bio-ethanol)* (in refs. [5,11]), Biodiesel (in ref. [9]), Biofuels (in refs. [5,11]).

3.6. Adoption of environmentally directed, technological solutions through integration with research work: PET recycling (in ref. [13]), chemical washing (in ref. [13]), Innovation (in ref. [5]), Automotive industry advances (in ref. [5]).

3.7. Implementation of environmentally oriented management programs: Ecodesign (in refs. [6,7]).

3.8. Adoption of evaluation methodological tools: Emergy accounting (in refs. [7,9,12]), Emergy analysis (in ref. [11]), Embodied energy (in ref. [9]), Materials flow accounting (in ref. [9]), Chemical exergy (in ref. [10]), LCA (in refs. [8,10,11]), LCI (in ref. [8]), EIA (in ref. [4]).

3.9. Regulatory policy: Although no paper of the collection adopted keywords correlated with regulatory legislation the roles that regulations play in the promotion of implementation of CP-oriented practices is explored is two. See refs. [4] and [5].

4. Overview of the activities and applied methodologies utilized in the ten papers of this special issue

It is interesting to note that the activities and methodologies addressed in the papers of this special issue cover a wide array of issues from work with renewable and non-renewable materials and energy. The documents provide the readers many valuable and practical illustrations of how they can implement CP concepts and practices so that they also engage in the transition to more sustainable societies. Although the environment is only one of the dimensions that form the triple bottom line (TBL) necessary to construct the sustainability framework, it is important to take into account that the biosphere contains, supplies and supports the other two dimensions. Therefore, maintenance of the natural capital, by means of environmentally directed CP practices, results in direct and indirect benefits to the socio-sphere and the economic-sphere.

The inclusion of papers was not limited due to methodological approach or focused activity, therefore, conceptual, as well as analytical and case studies are included. We hope the reader learns much about a wide spectrum of viable ways to make improvements by implementing CP approaches.

An overview based on the activities, content and type of methodological approach in each article is sequently presented in the following:

(a) In the first article, "Informal knowledge processes: the underpinning for sustainable outcomes in EIA?" authored by Bond, Viegas, Coelho and Selig, a conceptual approach of the Environmental Impact Assessment (EIA) principles was used and, after presenting the problematic framework, a case study was used to gain information and to interact with the EIA team [4]. The case study addressed issues pertaining to the extension of a landfill in Rio Grande do Sul, Brazil. The authors discussed how the diverse and sometimes conflicting interpretations of the terms "sustainability" and "interdisciplinarity", limits and puts at risk the adoption of the EIA and use a case study to evidence the role of informal knowledge. The authors affirmed that the EIA, that was developed four decades ago, in response to fulfillment of the requirements of the U.S. National Environmental Policy Act. (NEPA), presents inherent assumptions of sustainability and interdisciplinarity. They illustrated the role of informal knowledge through results extracted from interviews with four professionals that comprise the EIA team. Results expressed that multidisciplinarity prevailed as professionals worked independently using their own methods and paradigms. "Sustainability" appears to have had no common definition among the EIA team members, although the "weak sustainability" understanding predominated. The authors concluded that it was possible to show that informal knowledge, which is not legally required, is essential for performing an effective EIA because it captures and handles features about team working, leadership and collaboration that go beyond the formal rules.

(b) In "Exploring Innovation in the Automotive Industry: New Technologies for Cleaner cars" by Zapata and Nieuwenhuis [5], the approach is conceptual and a number of alternative case studies were used to focus the paper. The paper focused upon the automotive industry in terms of alternative fuels and alternative powertrain technologies. The concepts of radical and incremental innovation were used in order to classify the alternative technologies and the roles emissions legislation has played in the introduction of new automotive technologies are discussed. The authors emphasized that the fundamental difference between radical and incremental innovation needs to be understood through the lenses of the economics of the motor industry. Since an alternative fuel is an energy source that can be used with no or minimal modification in existing engines, it is classified as an incremental innovation by the authors. On the other hand, 'alternative powertrain' was classified as radical innovation because of the necessity of the replacement of existing internal combustion engines with a different system.

(c) In "Ecodesign Methods Focused on Remanufacturing," authored by Pigosso, Zanette, Guelere Filho and Ometto, the conceptual approach was used for performing a critical literature revision [6]. The object of the research was the integration of Ecodesign and "end-of-life" strategies for reducing the environmental impacts of the products final disposal. Special attention was paid to remanufacturing, the importance of which is rapidly increasing in the international scenario in face of regulations concerning the extended producer's responsibilities. By adopting criteria which include representativity, relevance and applicability, the authors revised five methods: Environmental Design Industrial Template (EDIT), D4N, Environmental Design Support Tool (EDST), Method to Assess the Adaptability of Products (MAAP) and Product Life cycle Planning (LCP). They concluded that all five methods emphasize the importance of planning for disassembly, already at the design phase as an economic strategy as well as to improve environmental quality, when addressing "End-of-life" strategies.

(d) In "Emergy as a tool for Ecodesign: Evaluating Materials and Selection for Beverage Packages in Brazil," authored by Almeida, Rodriguez, Bonilla and Giannetti, the analytical approach was based on the emergy methodology and used data from case studies [7]. The systems under study were PET bottles and aluminum cans for beverage packaging in Brazil. The proposal was the insertion of 'emergy environmental accounting' as a complementary tool to assist Ecodesign tools to support designers' decisions in material selection and choice of alternative processes. It is increasingly urgent that such combinations of tools be used so as to be more effective in meeting the increasing worldwide demand for integration of environmental and economic assessments in a quantitative and sustained ways. The authors illustrated the application of the proposed method by simulating a real decision-making situation: the necessity of choosing between different materials (PET and aluminum without and with recycling) for beverage packaging purposes under Brazilian recyclability requirements. Emergy-based results extracted from the procedure application enabled the authors to affirm that the best choice among the four options is the production of recycled PET bottles.

(e) In "Life Cycle Inventory for Hydroelectric Generation: a Brazilian Case Study" by Ribeiro and da Silva, the analytical approach of LCI methodology based on data of a case study was used [8]. In this case, the activity explored was hydroelectric generation at the Itaipu dam, responsible for generating 23.8% of Brazil's electricity consumption. The authors argued that the lack of a Brazilian dataset resulted in difficulties to diffuse the LCA methodology within the country and since energy is such an important element for most products life cycles, appropriate LCIs on energy are crucial. Due to prevalence of hydropower within the Brazilian electricity matrix, the frequently used LCIs cannot be adopted to represent local conditions. The life cycle boundaries adopted in their work included construction and operation of the dam, life cycles of the most important materials and energy consumption, as well as construction site operation, emissions from reservoir flooding, material and worker transportation, and

earthworks. The study identified the environmental hotspots of the Itaipu LCI, as the following: emission of greenhouse gases at the reservoir; water and energy consumption, CO, particulates, SO_x and NO_x emissions at the steel life-cycle; water and energy consumption, CO_2 and particulate emissions at cement life-cycle; diesel consumption and NO_x emissions at operation of civil construction machines.

(f) In "Integrated Environmental Assessment of Biodiesel Production from Soybean in Brazil," by Cavalett and Ortega, an analytical study was done with data extracted from a case study [9]. The activity under research was biodiesel production; it addressed the whole supply chain from soybean planting to biodiesel production. The methodological basis included Emergy accounting, embodied energy and material flow accounting. The authors emphasized that the claimed worldwide benefits, related to greenhouse gases emissions and rural development, are not definitive when the whole production chain is properly evaluated. Results showed that soybean-based diesel is a questionable alternative due to direct pollution (fertilizers, agrochemicals, pesticides) and due to other environmental impacts (soil loss, energy, material, water and extensive land use). Calculated figures evidenced that 30.7 g CO_2 are released per MJ delivered compared with 100 g CO_2 per MJ for commercial diesel. Although that corresponds to almost 70% less than common diesel, biodiesel is not totally climate neutral. Emergy assessment results revealed a higher demand for direct and indirect environmental support than for the production of fossil fuels. The methodology also supplied a renewability of 31%, which is a very low value. The authors also underscored that more positive attributes could be obtained by clustering the biodiesel production with other agro industries and by taking full advantage of valuable co-products.

(g) In "Atmospheric Impacts of the Life Cycle Emissions of Fuel Ethanol in Brazil: Based on Chemical Exergy," by Ometto and Roma, an analytical procedure was used to perform Chemical Exergy analyses based upon data from a case study [10]. In this case, the system included the whole life cycle of bioethanol from the agricultural phase from sugar cane to ethanol production. The authors argued that since the main environmental impacts resulting from the life cycle of ethanol correspond to atmospheric emissions, chemical exergy is a good methodological tool to quantitative assessment. The life cycle included aspects of agricultural, industrial, transportation, recycling and usage. Results showed that the exergy loss from the life cycle emissions to the atmosphere represents 1.21% of the ethanol exergy. The authors observed that the activity that contributes most to atmospheric emission in terms of chemical exergy losses is during the burning of the sugar cane residues. Improvement suggestions such as harvesting the sugar cane without burning, adoption of renewable fuels in tractors, trucks and buses and transportation optimization were provided in order to improve the environmental quality and efficiency.

(h) In "Sustainability Assessment of Large Scale Ethanol Production from Sugar cane," by Pereira and Ortega, two methodological tools, Emergy accounting and fossil fuel embodied energy, were used to analytically evaluate data from a case study [11]. The system under study was bioethanol production including farm and industrial production phases, but differently from the latter paper, concerning also in bioethanol, the methodological approach used here focused on input resources. Thus, although the system is analogous, the methodological tools adopted in the two papers focused on different aspects: the latter on emissions and this paper on resources that enter the system. The authors argued that although biofuels have been presented as an important option for energy supply due to their intrinsic renewability and neutralization of greenhouse gases emissions, a more complete paramount should be offered addressing points such as soil degradation, natural ecosystem destruction and competition for the use of arable land. Results showed that during ethanol production, because of direct and indirect oil consumption, there is a net release of CO_2 with the agricultural phase being responsible for 80% of the releases. The transformity of ethanol is about the same as those calculated for fossil fuels and its renewability is 30%, a very low value. The authors suggested some solutions: less dependence of the crop production efforts on fossil fuel by their replacement with biofuels and by increasing energy use efficiency. They also proposed the incorporation of a support area to compensate the emitted greenhouse gases.

(i) In "Sustainability Assessment of a Giant Bamboo plantation in Brazil: Exploring the Influence of Labour, Time and Space," by Bonilla, Guarnetti, Almeida and Giannetti, the authors performed an analytical evaluation by using Emergy accounting methodology [12]. Data were extracted from a case study of bamboo production in Brazil. The importance of Bamboo is increasing worldwide since it has become an alternative instead of native or reforested wood. From an environmental point of view, bamboo plants rapidly sequester atmospheric carbon. Since emergy methodology enables one to calculate all the direct and indirect resources that enter the system by using the same metric, the diverse flows were identified and compared. The influence of labour on the total emergy flow as well as on the emergy indices was evaluated. An exploratory discussion on sustainability and its relationships with time and space was also reported. Time was discussed in terms of the capacity for the environment to provide the necessary resources to the systems. Space was evaluated by the indirect area used by the systems to ensure resource supplies. It was observed through the emergy sustainability index (ESI), that the bamboo plantation operates, depending on the conditions, within the unsustainable and the short-term sustainability region. The authors proposed a "compensatory area" that would act as a counterbalance to increase the EIS value within an acceptable interval.

(j) In "Additional Steps in Mechanical Recycling of PET," by Mancini, Schwartzman, Nogueira, Kagohara and Zanin, an analytical approach, based in laboratory scale experimental data, was presented [13]. The system under study was the mechanical recycling of PET. The authors concluded by elemental analysis, gas chromatography coupled to mass spectrometry and thermogravimetry that PET obtained after the inclusion of an additional chemical step presented better properties than the one normally obtained through conventional mechanical recycling only. The new step consisted in immersion of the PET in sodium hydroxide solution; this created a new surface, which is cleaner than the original. The authors also discussed the optimized procedures employed to obtain high purity terephthalic acid (TPA) from the "peeled" polymer produced during chemical washing. Although both the recycled PET and the TPA are closer, in technical terms, to the virgin material, they are not recommended for direct contact with food, since they may contain impurities.

5. Concluding remarks

As stated, no constraints were imposed on topics to be addressed in the papers selected for this special issue, provided that they were within its scope.

The topic of biofuels is repeatedly addressed; this reflects the worldwide concern on the urgency of the use and development of more renewable fuels and other improved energy technologies. The public perception of the central importance of bio-energy has caused many to only focus on the positive aspects of biofuels and thereby, avoiding their inherent limitations. Their real contributions toward a more sustainable world can only be accessed through a carefully performed, life cycle approach that enables researchers to thoroughly cover all phases from the plantation to fuel production and usage. By becoming more fully aware of the problems and limitations and having identified the weak-points, it is increasingly possible to test and implement improved practices to prevent or to minimize the negative impacts of bio-energy production and usage.

The necessity of using methodologically sound tools in order to correctly assess the real environmental costs and benefits of any practice is explored extensively in this special issue. The conclusion is that it is crucial to properly use appropriate assessment methodologies in supporting decision-making; it is also important to identify where improvements need to be made in the decision-support tools and in their usage. Creation of databases capable of reflecting local or specific conditions were also highlighted as a *necessary condition* to obtain more regionally relevant assessment results.

The role of regulatory legislation as a promoter of technological improvements, managerial strategies and environmentally oriented projects to ensure compliance is underscored in this special issue. The inter-relationships among policy makers, environmentally and ethically conscious consumers, responsible producers, evolving CSR requirements in international trade and proper worker's rights are complex due to diverse interests and time-frames. However, it is increasingly evident that transparent exchange of information and environmentally oriented education programs, at all age levels, is an essential component of a holistic approach to sustainable societal development.

It has become clear that new legislation, which requires that companies engage in waste minimization and extended producer responsibility from the product design phase, to the production phase, to the consumer phase, to the end-of-life management of the 'dead' products phase, can be an increasingly important catalyst for changes in corporate and societal attitudes, values, paradigms and practices.

Environmentally, oriented educational programs, which are essential elements in the sustainability transition, are unfortunately, still not sufficiently explored or adopted in this region of the world. Information relating environmental concerns, cleaner technologies, waste treatment, end-of-life management of products, and cleaner energies will enable every citizen to become more aware and involved. It will also provide tools for them to pressure governments to develop and to enforce proper, proactive legislation to help ensure that producers strive to work within the TBL framework for both and the short-and long-term.

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