Investigating the environmental damage: a detailed study about the main reference methods for economic and social aspects integration

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Abstract
In 2013, ISPRA (Italian National Institute for Environmental Protection and Research*)* and the Department of Business Studies of Roma Tre University signed a cooperative framework agreement to launch a joint research project for the development and the implementation of methodologies and tools able to accurately quantifying and assessing Environmental Damage, also considering the Life Cycle Assessment (LCA) approach and its application in the field (M.I.D.A. Research Program, Methodologies for environmental damage individuation).
In this view, the scientific literature on the Life Cycle Impact Assessment (LCIA) has been reviewed, in order to find those LCIA methods that could be suited to accomplish the goals of Environmental Damage Assessment. Recent developments are leading to advances in the practice of LCIA. Life Cycle Assessment (LCA) is definitely a useful tool in order to assess and quantify environmental impacts, but its appropriateness as a methodology to address the requirements of environmental damage remains uncertain.
As a first step, we have defined the environmental damage and so fully understand its requirements. Then, we have tried to find how, under the light of recent developments, the LCA methodology could offer opportunities to match these specific requirements.
After that, in the second phase we have considered different aspects for the assessment and quantification of environmental damage, including the risk assessment methods, and integrated it in a Corporate Social Responsibility (CSR) Strategy in a managerial perspective.
This paper shown these actual results and the outlook of these research project goals.

Keywords: *Environmental Damage, Risk Assessment, Environmental damage indicators, WTP, DALY, Impact Pathway*

1. Introduction

In M.I.D.A., the scientific literature on the Life Cycle Impact Assessment (LCIA) has been reviewed in order to find those LCIA methods, which could be suited to accomplish the goals of Environmental Damage Assessment. Recent developments are leading to advances in the practice of LCIA. Industrial activities and, more generally, the anthropogenic ones, which could be considered responsible for the generation of pollution, will, in principle, the risk of contamination of environmental matrices and degradation of ecosystems, constituting, for the most, serious threat to human health, for the causation of damage to material goods, and for the loss, sometimes irreversible biodiversity. In mature environmental regulatory systems, this risk is reflected in the principle of liability of owners and operators of such activities to the numbers of their consequences to the environment ("pay polluter principle").
Liability for environmental damage, in many industrialized Western countries, is seen as an obligation for the person responsible to bear the costs of environmental restoration. This obligation, under the strict liability regime primarily applied in OECD countries, does not require proof of negligence or non-compliance. Cleaning is usually carried out by the person responsible for the damage under an administrative or judicial order, in accordance with

a specific restoration project. In cases where there is a threat to public health or environmental emergency in general, the authorities may proceed directly with the required preventive/remedial actions, only to recover remediation costs from responsible parties.
Today, there are different methodological approach to quantify the environmental damage but no one universally adopted that allows the comparison of results between different companies in the same sector. Based on the literature review, the purpose of this research is to analyze the different methods for providing the value of the environmental damage (real or potential) in order to facilitate the implementation of CSR Strategy and managing Risk assessment.
The purpose of this paper is to show the actual results and the future outlook.
In the following sections, the environmental Damage assessment and the introduction on Life Cycle Assessment (LCA) principles are presented (section 2), while section 3 considers the economic methods for environmental damage evaluation, section 4 includes the Risk Assessment methods and the concept of corporate social responsibility (CSR) are introduced through the literature, the final consideration and the global approach are presented in discussion and conclusions (section 5).

2. Environmental Damage and Life Cycle Assessment

The notion of Environmental damage is defined in different ways, according to the different legal liability systems. In general, "Environmental Damage" refers to the damages and threats to the environment as a result of environmental pollution, such as those arising from an accident. It mainly includes costs to implement necessary and reasonable measures to prevent the expansion of environmental pollution, and to remediate and/or restore the damaged environment. In general, any environmental damage assessment should be site-specific, including and integrating different approaches (economic, legislative, technical and others), in order to identify, quantify and value environmental injuries.
Various international and national laws and regulations have been enacted to hold polluters liable for the cleanup of released hazardous substances and some of these regulations further require the polluter to restore any injured natural resources and accompanying services to their baseline condition. In Europe, Directive 2004/35/EC of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage (ELD), establishes a framework based on the polluter pays principle to prevent and remedy environmental damage.
In the US, the definition of damage to the environment is defined as costs related to response actions associated with the inflicted harm. US law talks about "damages for injury to, destruction of, or loss of natural resources, including the reasonable costs of assessing such injury, destruction, or loss". The US definition of natural resources is broad in scope and encompasses not only more commonly considered resources such as land, surface waters, wildlife and fish, but also air, groundwater, drinking water supplies and any other resources.
More in general, the assessment of environmental damage in OECD countries is primarily based on resource equivalency analysis to estimate the needs and costs of restoring affected resources or environmental services.
The remediation scope may be mandated by law or left to the discretion of the competent authority, which determines specific measures using criteria such as technical feasibility, effectiveness and efficiency.
The assessment of environmental damage is the process of determining the degree of injury to natural resources caused by a pollutant, the amount of restoration required to return the injured resource to a preinjury condition and the scope of associated environmental rehabilitation efforts. This assessment can be broken down into five general steps:

- release of a hazardous substance,
- exposure and injury of natural resources,
- assessing the extent of any injury,
- determining the amount or scale of actions required to recover any injured resources and services,
- restoring or rehabilitating these resources and services

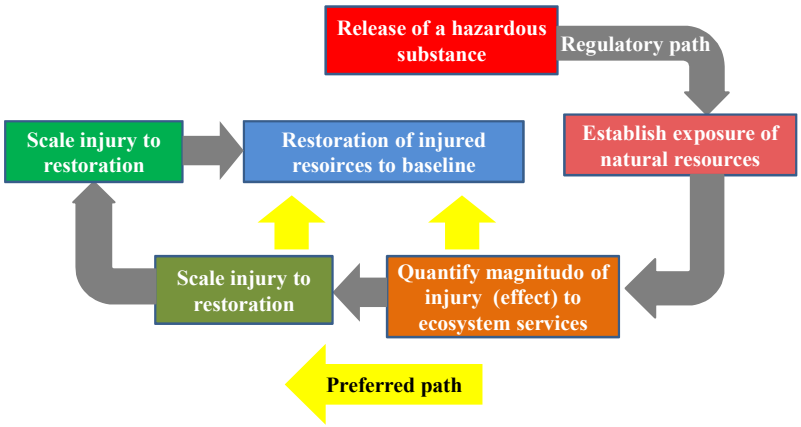

Fig. 1: Process scheme of environmental damage assessment. Our Elaboration.

Life Cycle Assessment (LCA) tries to model the complex interaction between a product/activity and the impacts on the environment. Historically, LCA and the related Impact Assessment (LCIA) methods have mostly relied on site-generic, not spatially resolved, models. Thus, LCIA ignored those fate and exposure characteristics, which were specified according to the conditions at the relevant locations. Here lies a source of discrepancy between modelled impact and the occurrence of actual impact. In recent years, the relevance of accounting for spatial differentiation has been increasingly discussed in the context of LCA. Thus, several spatially distributed fate and transport models of chemicals, i.e. models allowing spatially explicit assessment of contaminants from a given spatial distribution of emission, were developed. Regionalization is recognized as an important step towards improving the accuracy and precision of life cycle assessment (LCA) results, thereby increasing its discriminatory power for comparative assessments. Many types of damage, such as acidification or eco-toxicological impacts on humans and ecosystems, often occur as regional or local impacts, making it important to evaluate them as a function of where the emission takes place. By regionalizing such impacts, decision-makers can have greater confidence in the non-global impacts presented in the LCA. The importance of performing a regionalized life cycle impact assessment (LCIA) consists in the availability of appropriate spatial scales for characterization factors that in the majority of impact categories are dependent on site-specific characteristics (e.g. population, soil types, climate factors, etc.).
Furthermore, the experience gained in the development of LCA methodology indicates that the essential role of ecosystem goods and services in sustaining all human activities is often ignored in engineering decision making, even in methods that are meant to encourage sustainability. In recent years, methods that are relevant to accounting for the role of nature were studied with the aim of bridging the gap between knowledge about ecosystem services and their direct and indirect role in supporting human activities. These include methods developed by ecologists for quantifying ecosystem services, by ecological economists for monetary valuation, and life cycle methods such as conventional life cycle assessment, thermodynamic methods for resource accounting such as exergy and emergy analysis, variations of the ecological footprint approach, and human appropriation of net primary productivity. Each approach has its strengths: economic methods are able to quantify the value of cultural services; LCA considers emissions and assesses their impact; emergy accounts for supporting services in terms of cumulative exergy; and ecological footprint is intuitively appealing and considers bio-capacity.

3. Economic and social aspects of environmental damage

Assign an economic value to air pollution and more generally, to an environmental good such as air quality requires some explanation.
There is talk of Total Economic Value (TEV), as the sum of individual value components that can assign an economic value to environmental goods, which obviously have no market. More specifically, the TEV components are:

1. Direct use value
2. Indirect use value
3. Option Value
4. Bequest value
5. Existence or intrinsic value

Where:

1. The direct use value is linked to the usefulness perceived by individuals with the use of well-considered and is a result of direct contact with it.
2. The indirect use value is the value attributed to an asset as it produces essential services for other resources and ecosystems.

3. The option value shall be a taxable value (or not use), because individuals can assign a value to a resource even apart from its actual use. It is related to the desire to ensure the availability of good to be able to benefit in the future.
4. The bequest value refers to the ability of future generations to enjoy the property in question.
5. The existence value or intrinsic, concerns the usefulness perceived by the parties for the sole fact that resources continue to exist, independent of the use of the same. It is due to ethical or moral arguments.

In any case, prior to the stage of economic evaluation, it is important to verify the relevance of the different components of the VET value, because the significance of each of these components with respect to the total economic value depends very much on the manner in which the individual benefits resource (economic value of air pollution).

In the absence of a market for an environmental good, its economic value is measured by the amount of money that can provide a utility equal to that produced in the asset. If we talk about environmental damage, such as air pollution, the effects can be configured as a negative change of the utility flow from an asset of collective use, i.e. air quality, and its monetary measure is equal to the sum capable of providing an equivalent utility flow.

Air pollution produces damage to human health and therefore influences the economic sphere of the human being, and for increased health care costs, both for the deterioration of the quality of people's lives, with consequences so on the social sphere. Estimate then these costs means identifying the economic cost which the public should support to tackle health care needed and the inconvenience resulting from the loss of collective and individual well-being.

Estimates, however, are anything but simple. It is now established the existence of a link between the presence of pollutants and damage to health, identified by the epidemiological literature, and enclosed in dose-response functions, namely a function that expresses the statistical relationship between the concentration of a specific contaminant and effect- damage human health. Formally, this relation is:

$$\Delta R = \beta . \Delta D$$

Where:

β = coefficient of the dose-response function

ΔD = change in dose

ΔR = change in response

In the case of air pollution, the exogenous variable is usually the level of
concentration of a pollutant, while the endogenous variable may be the number of deaths or the number of certain illnesses or hospitalizations. Therefore, the efforts of economists have focused on two types of estimates:

- The Mortality costs,
- The morbidity costs.

It should also be taken into account that the costs attributable to the lower probability of survival of an individual are related not only to the direct losses associated with future deaths, such as loss of production or health care expenditures to tackle the disease, but as costs that may be less obvious but not secondary, such as:

- The moral damage, i.e. the state of suffering created by the disease regardless of the possibility to generate income;
- Affective costs, generated by biological and moral damage suffered by the individual and the family of the victim;
- Loss of future production, which constitutes a cost not only for loss of individual income, but for the entire community.

The approach used by the EEA, with the exception of carbon dioxide, is based on IPA, (Impact Pathway Approach), a method originally developed in the 90s in a collaborative program between the European Commission and the US Department of Energy, called ExternE. This approach consists of a series of logical steps which, starting from the emissions of a pollutant, determine the impact the product and measured in monetary terms the cost of the damage generated.

4. Introducing Risk Assessment tools and Social Aspects

Environmental risk management and risk assessment is the process of identifying, evaluating, selecting, and implementing actions to reduce risk to human health and to ecosystems (USPCC RARM, 1997). In the industries, in order to achieve a competitive advantage and maximize long-term profits, it is crucial to adopt a socially responsible behavior, monitoring and responding to economic, environmental and social expectations of all its stakeholders (McWilliams, 2000). This research step provides an overview of the state of the art and of the basics of literature useful for creating a baseline scenario. In the definition of a proper risk management strategy, it should be considered the assessment of exposure to environmental risk in all its variables.

The authors conducted a systematic review of the literature analyzing the publications (books, scientific articles and reports) on the environmental damage by querying the databases with the keywords "environmental damage" and "environmental risk assessment" and "economic value of environmental damage". Given that sample, the

results have been classified according to the following set of dimensions and characteristics. 1. Item as Report (R), Scientific Journal (SJ), Book (B); 2. Objectives; 3. In the Table 1 the authors present the main results obtained.

Authors	Title	1. Item	2. Objectives	3. Methodological features
Amann et al, 1998	The revision of the air quality legislation in the European Union related to ground level ozone.	SJ	Incidence rate of benefits on human health in the implementation of environmental policies	WTP
Atkinson et al,2006	Cost benefits analysis and the environment: recent development	B	Incidence rate of benefits on human health	Cost-effectiveness analysis integrating information on economic, technical, physical and biological aspects of ozone pollution and abatement
Bickel et al. 2013	Environmental external costs of transport	B	Impact pathway for estimating marginal environmental cost of transport	WTP, Bottom-up approach
Borruso et al 2001	Methodology for the estimation of the cost of air pollution and noise	B	Demonstration of the reasons why quantifying the effects of pollution in terms of life years lost rather than the number of deaths is better if we consider life expectancy	DALY
Desaigueset al, 2007	Final Report on the monetary valuation of mortality and morbidity risks from air pollution	R	Demonstration of the appropriate metric to assess the impact of atmospheric pollution on human health, life expectancy.	Life expectancy
ExternE, 1995-2005	External cost of Energy http://www.externe.info/externe_d7/?q=node/4	R	Impact Pathway for the assessment of external impacts and associated costs resulting from the supply and use of energy	Impact pathways approach methodology
Hainoun et al., 2010	Estimating the health damage costs of syrian electricity generation system using impact pathway approach	SJ	The impact pathways approach methodology for the economic quantification of damage	Impact pathways approach methodology
Holland and Krewitt, 1996	Benefits of an Acidification strategy for the European Union reductions of SOx,NOx, NH3 in the European Union.	R	The concept of 'total economic value' and evaluation techniques could to be use.	VOLY and VSL
Kahn J. Et al, 2007	As China Roars, Pollution Reaches Deadly Extremes	B	Environmental damage definition for China	No Methods
Krewitt et al, 1998	Application of the impact pathway analysis in the context of LCA	SJ	The impact pathways approach methodology for the economic quantification of damage	Impact pathways approach methodology
Rabl et al.,2003	Interpretation of air pollution mortality: number of deaths or years of life lost?	SJ	Criterion the years of life lost rather than the number of deaths. Explanation and demonstration of this statement.	DALY

Table 1: Sample of the literature exanimate and overview of the different methods considered.

In the analyzed literature, the indicators mainly took into consideration by scholars are the WTP, the DALY and the Impact Pathway Approach. Although these tools were not specifically designed for the evaluation of environmental damage, their application in several projects encourages the debate about their validity to be applied in the field. In the analysis, the most common methods founded are the WTP present in the Impact Pathway approach methodology and the DALY. The Impact pathway approach estimates environmental costs and benefits starting the assessment from the emissions sources, then deriving the physical impacts and finally evaluating the physical

impacts in monetary terms. The monetary evaluation is performed according to the welfare theory and so it accounts as the welfare losses for individuals. The DALY is the reference indicator used by the WHO to give a value of the several diseases overall burden. This method does not provide to the single company its total value of environmental damage incurred, because it was created as a general method applicable to a production sector. Thus, if a company adopts this method, it must add also other values such as medical expenses incurred by workers, or by the company itself, or the economic value of the potential damage to the image and reputation. Therefore, this method could be used as a starting point for a company to be able to make complete estimates, customizing it with the factors that best correspond to its knowledge needs.

5. Discussion and Conclusions

The interaction between a product or a process activity and the environment is a very complex issue to analyze in order to define all the variables to include in the general model.
The developments in LCA methodology could offer new opportunities in the assessments of environmental damage, especially helpful in valuing the exposure of natural resources and determining the effects to ecosystem services. In any way, further improvements of characterization methods for toxic impacts, as well as expansion of remediation-relevant LCI databases are still necessary to enhance the appropriate applicability of LCA methodology for the assessment of environmental damages.
The economic issue through the VET method application is only a part of the real economic incidence of the environmental damage. The sum of individual value components that can assign an economic value to environmental goods, which obviously have no market, but does not include the externalities.
In a Commodity Science perspective, the Corporate Social Responsibility (CSR) represents the industrial point of view of global sustainability implementation focusing on economic and social aspect of damage and firm's viewpoint.
Environmental damage in order to be included in CSR's strategies has to be integrated in enterprises "vision" through actual programs of Environmental Responsibility. The classic approach of CSR (Friedman, 1962) consider as the only responsibility on charge on enterprises the making of profit followed by the free market's logics and not caring at all of other kind of responsibilities.
In Neoclassic models, corporate social responsibility plays a major role rather than in classic theories as enterprises, even if make profit still remains their first target, have to act following a "moral minimum".
However, environmental safety doesn't fit in the "moral minimum" because a balance between environmental damage and utility generated by goods and services produced by firms, must exists.
This kind of balance takes place by "social consensus" through the market mechanisms. For this reason, also for the neoclassic model, environmental damage seems not to be included in CSR meaning.
In order to be integrated in enterprises strategies, environmental issues must be relevant on the economic side at least in the long period. CSR models based on standard market logics and economic growth will be inadequate in the future, both on the environmental and economic point of view.
A complete environmental responsibility can be obtained through the concept of sustainable development in order to have aholistic and "eco-centric" view.
In addition, environmental responsibility is based on three basic principles. The first one refers to the use of renewable resources that cannot overcome their regeneration rate otherwise, the damage repair would be too slow and expensive. The use of non-renewable sources, contained in the second principle, must not overcame the development of new alternatives rate and the loss of opportunity or in other words the loss of productive capacity caused by the use of non-renewable resources. Last principle considers the production of waste and emissions that cannot be superior of the ecosystem absorption rate with the aim of minimize inefficiency that must be considered as an environmental and economic injustice.
Actually, the main indicators taken into consideration are Willingness To Pay (WTP) and the Disability Adjusted of Life Year Indicator (DALY). The first one measures the economic value attributed to the "human health", whilst the second expresses the number of years lost because of illness, disability or premature death. With their use, it is possible to calculate the amount of revenues lost due to the illness of workers. Therefore, the Economic Value of Environmental Damage made by the company towards its employees can be expressed as the difference between the economic value of the planned production on all available work days and the economic value of production calculated for DALY days. The use of these two authoritative indicators gives credibility and reliability to this method, but they are not generalized and harmonized.
The studies examined in this work adhere to the criteria and lend to be suitable tools for implementing a comprehensive CSR strategy. In the future, a new method can be created and implemented starting from the existing ones. In particular, new parts that affect other categories of stakeholders could be developed, in order to achieve a comprehensive approach that addresses the relationship between a company that wants to implement CSR and relations with its stakeholder in a complete way.

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