Transactions on Ecology and the Environment vol 46, © 2001 WIT Press, www.witpress.com, ISSN 1743-3541

Effects on the ecosystem of ceramics production in Sassuolo (Italy)

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Abstract

The problem of local pollution is often related to the characteristics of the productive system, especially when firms of a certain type are concentrated in a small area. An emblematic example is the Sassuolo district (province of Modena, Italy), in which a large part of the Italian production of ceramics is concentrated. We present a thermodynamic analysis of the sustainable use of resources, focusing the attention on the district of Sassuolo. The methodology that is used is the emergy evaluation. Emergy represents the solar energy that is directly and indirectly used up to produce a flow or a storage. The analysis shows that the Sassuolo district represents the peak of non-sustainability of the whole province, with a huge consumption of non-renewable primary resources, both imported and local. The use of the energy resources and the transport of raw and transformed materials are key problems of the district. Emergy related indexes are calculated to understand which of the components that contribute to the system are likely to be limiting factors for future development. The role of the ceramics industry is considered in the consumption of energy and materials. Results show a low level of long-term sustainability, especially if compared with other industrial sectors in the province of Modena.

Different types of factories for ceramics production are evaluated, representing a good sample of the different methods of production of the area. This analysis has shown which of these has higher levels of sustainability with respect to the others.

1 Introduction

Today, our society consumes and exploits the environment in a frantic way, which is considered by many to overshoot the carrying capacity of the earth.

The use of resources and the discharge of wastes are no more compatible with the cycles of nature. In particular, the depletion of non-renewable resources, will not allow the future generations to meet their own needs. Hence, the realty is just the opposite of the meaning of Sustainable Development stated by World Commission on Environment and Development (WCED) in 1987.

To take into account all the resources (natural and manufactured) sustaining a system and to evaluate the environmental work to make them available, we adopt the concept of *Emergy* by Howard Odum. He defined emergy as the quantity of solar energy necessary (directly or indirectly) to obtain a product or an energy flow in a given process. Solar energy is the common basis of all energy flows occurring in the biosphere. The greater the emergy flow necessary to sustain a process, the greater the quantity of solar energy consumed or, in other words, the greater the environmental cost. Hence emergy is the memory of all the solar energy consumed during the process. Emergy is measured in Joules, but not indistinct Joules, solar energy Joules, that Odum called *sej* [1].

Emergy is the common basis on which a system of environmental accounting can be built. To convert all the energy inputs in sej, the concept of *Transformity* is introduced. Solar Transformity is defined as the emergy required per unit product or service [2] or as the solar energy directly or indirectly necessary to obtain one unit (Joule) of another type of energy. In essence, the higher the transformity of a resource or energy, the greater the environmental activity necessary to produce it. So transformity is an indicator of past environmental contribution to a resource and future load on environmental systems that will result from its use [3]. For systems with the same output, such as different ceramic tiles production, the lower the transformity, the higher is the efficiency of the system in the production [4].

Once all the input are classified in renewable (R) and non-renewable (N) resources and local (L) (natural) and imported (F) inputs, some ratios of the environmental stress and of the efficiency of the process can be provided.

The *environmental loading ratio* (ELR) is the ratio of purchased and non-renewable indigenous emergy to renewable environmental emergy:

$$ELR = \frac{N+F}{R} \tag{1}$$

ELR is an indicator of the pressure of the process on the local ecosystem (even if the damage is not only local depending on where the resources are taken) and can be considered a measure of the ecosystem stress due to production activity. A high value of the ELR, often due to a high technological level in the use of resources, indicates high environmental stress, because local environmental cycles are overloaded.

The *emergy yield ratio* is the emergy of an output (Y) divided by the emergy of those inputs (F) from the economic sector (i.e. non provided for free by the environment):

$$EYR = \frac{R + N + F}{F} \tag{2}$$

EYR is an indicator of the yield compared to inputs other than local and gives a measure of the ability of the process to exploit local resources.

This approach can be used to give information about the sustainability of a production system as well as of systems at a territorial level. In the present research we studied three types of ceramic tiles production selected by the Province of Modena together with the association of ceramic producers (Assopiastrelle) in the district of Sassuolo. We examined how the entire ceramic sector of Sassuolo affects the sustainability (or unsustainability) of the whole territory of the Province of Modena.

An interesting development of this study would be a comparative analysis of the Italian (Sassuolo) and Spanish (Castellon de la Plana) ceramics productions, since they are two of the main industrial poles in Europe.

2 The ceramic industry

More than 120 factories producing ceramic tiles operate into the industrial district of Sassuolo. They consume and transform huge quantities of raw materials (especially clay) and energy to obtain the 80% of the whole national production of ceramic tiles.

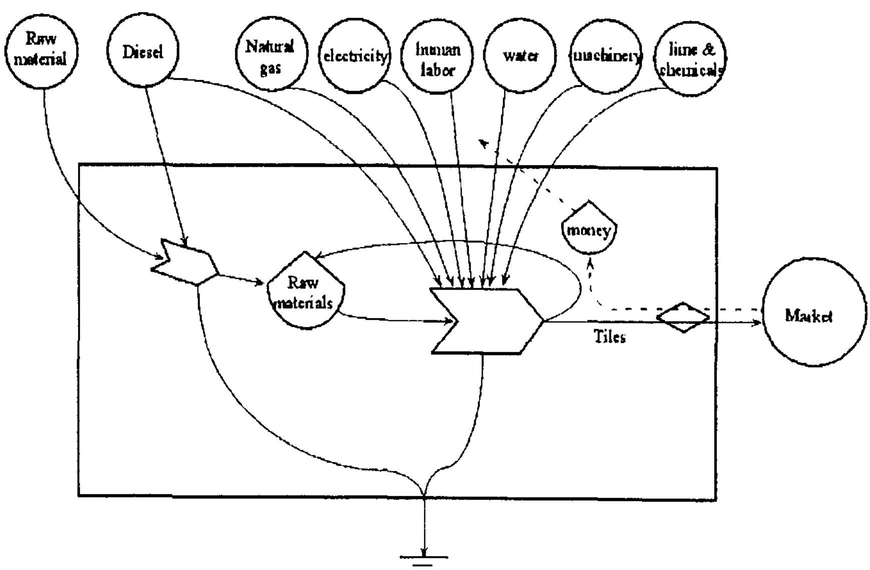

Figure 1: Energy system diagram of a ceramic tile production (3rd factory).

Transactions on Ecology and the Environment vol 46, © 2001 WIT Press, www.witpress.com, ISSN 1743-3541

While the problems related to the quantity and quality of emission and pollution are subject to high levels of control by the authorities, our analysis is focused on the right use of resources, in particular on the depletion of non renewable ones both inside and outside the district due to the industrial activity.

The three factories selected are representative of different technologies and quantity and type of ceramic tiles.

The method of environmental accounting based on emergy requires the construction of an energy system diagram and of a group of tables for each factory under study.

In Figure 1, a ceramic tiles production process is represented by the interaction of all the inputs, such as local and purchased raw materials (minerals), energy inputs, human labor, machinery etc., to obtain an output for the market. Table 1 is the summary of the inputs and the output of one of the three productive systems expressed in terms of emergy.

Table 1. Emergy evaluation of ceramic tiles production (3rd factory).

Item		Unit	Solar Transformity (sej/unit)	Solar Emergy	Type
TRANSPORT OF RAW MATERIAL TO THE FIRM					
1 Diesel	3.98E+13	J	6.60E+04	2.62E+18	N,F
PRODUCTION					
2 Raw Material					
Clay	4.19E+10	g	2.00E+09	8.37E+19	N,F
Feldspar	5.91E+10	g	1.00E+09	5.91E+19	N,F
3 Electricity	6.45E+13	J	2.00E+05	1.29E+19	N,F
4 Natural gas	4.90E+11	J	4.80E+04	2.35E+16	N,F
5 Diesel and lubricants	4.45E+12	J	6.60E+04	2.94E+17	N,F
6 Water	7.30E+10	g	1.25E+06	9.13E+16	N,5%F
7 Human labor	1.75E+11	J	7.38E+06	1.29E+18	10%R,F
8 Machinery	1.36E+08	g	6.70E+09	9.11E+17	N,F
9 Lime	2.40E+07	g	3.80E+08	9.12E+15	N,F
(A) Local Renewable Resources (10% of item 7)				1.29E+17	
(B) Local non-Renewable Resources (95% of item 6)				8.67E+16	
(C) Purchased Resources (sum of items 1-9, with 90% of item 7 and 5% of 6)				1.61E+20	
Total Emergy used for the ceramic tile production				1.61E+20	
PRODUCT					
10 Tiles	3.50E+06	m^2	4.60E+13		
	7.70E+10	g	2.09E+09		

Legend: R=renewable resource; N=non-renewable resource; F=resource purchased from outside

The first two factories produce single firing tiles but the first is the biggest one and it adopts also more advanced technologies. So its production is $1.04 \cdot 10^{11}$ g/yr while the second factory produces $5.40 \cdot 10^{10}$ g/yr, but the consumption of the first one in terms of energy and raw materials is obviously larger. The transformities of the two outputs are respectively $1.80 \cdot 10^{9}$ sej/g and $1.62 \cdot 10^{9}$ sej/g and indicate that the second firm is more efficient. The most interesting point is that it uses only natural gas as a fuel, co-generating the electricity necessary for the productive process.

The third factory, whose data are represented in table 1, produces porcelain stoneware, which is characterized by a bigger quantity of raw material per unit of output, by a better quality of product and by a higher price for the buyer. The transformity of its output is the biggest one, measuring $2.09 \cdot 10^{9}$ sej/g.

In Table 2 the main data and results of the analysis is presented for the three factories.

Table 2. Comparison of emergy results of the three firms.

	Units	Firm # 1 Single firing	Firm # 2 Single firing	Firm # 3 Porcelain Stoneware
Tile production	*g*	1.04E+11	5.40E+10	7.70E+10
	m²	5.78E+06	3.00E+06	3.50E+06
Emergy	*sej*	1.87E+20	8.77E+19	1.61E+20
Transformity	*sej/m²*	3.23E+13	2.92E+13	4.60E+13
	sej/g	1.80E+09	1.62E+09	2.09E+09
EYR		1.0007	1.0010	1.0013
ELR		2159	1013	1247

While the higher quality of porcelain stoneware justifies the higher transformity of the third firm, the worst system in terms of sustainability is represented by the first and biggest one, as the environmental loading ratio demonstrates (ELR_1 = 2159). Anyway, the value of the three ELR is very high due to the large use of non-renewable raw materials and energy, even if the use of natural gas instead of fossil fuels per unit of output and the co-generation of electricity permit the second factory to have a lower impact on environment (ELR_2 = 1013).

Although the third firm presents the same problems of the other ones, its better results (ELR_3 = 1247) are consistent with the higher quality of the output and with a higher amount of renewable inputs (a percentage of human labor) per unit of product. The situation for the third factory implies also better performances in terms of emergy yield ratio (1.0013) even if this value for the three firms is very close to 1.

3 The sustainability at a territorial level: the case of Sassuolo

Industrial activity in Sassuolo produces negative effects on the local ecosystem, compromising the sustainability of the whole district.

One of the key points is the problem of transportation of raw material and of products. The emissions of CO_2 and the overcrowding of roads are important elements of the unsustainability of this territory and surrounding areas are involved too: for example, as we can see in the sustainability analysis of the entire Province of Modena [5], while ELR of Sassuolo is 112.3 compared with 3.88 of the Hill-mountain district, the Emergy per-person index of the latter ($2.58 \cdot 10^{16}$) is higher than the one of other and more industrialized districts due to commuting and transportation.

ELR represents the ratio of non-renewable emergy (both local and purchased) to renewable environmental emergy. This ratio is 9.47 for Italy [2] and it's 21.16 for the Province of Modena [5]. Thus the value of ELR of Sassuolo is 12 times the national ELR and 5 times the provincial one. This means that Sassuolo can be considered as a "peak" of unsustainability.

The use of non-renewable resources, in particular raw materials (clay, feldspar), represents almost 80% of the emergy required to produce ceramic tiles. Most of those resources are imported from other ecosystems (or economies, from a commercial point of view) causing a structural fragility of the system due to the dependence from the residual availability of resources outside the district. As sustainability is a global problem, if a system exploits non-renewables which are imported from outside, it shifts factors of unsustainability elsewhere without solving its own environmental impact.

Finally, the depletion of non-renewables causes irreversible alteration on the ecosystems and on their equilibria and furthermore the effects of the anthropic pressure are not completely predictable in the long term. This means uncertainty about the damages we are perpetrating today to the detriment of future generations.

4 Conclusions

The ecosystems offer and regenerate resources at a given rate. If humans use them at a higher rate, anthropic systems are bound to collapse: in other words they are not able to survive indefinitely, so they are not sustainable. As Herman Daly stated, non-renewable resources "cannot be maintained intact short of nonuse [...] but it is possible to exploit them in a quasi-sustainable manner by limiting the rate of depletion to the rate of creation of renewable substitute" [6].

The analysis of the district of Sassuolo summarizes how environmental problems can affect both the future stability of industrial production and the sustainability of the whole territory. The former question has to do with the present and future availability of raw material and energy necessary to support the productive system; the latter one has to do with the harmful effects of human activity at local level, i.e. emission of CO_2 and of other greenhouse gasses related to production and transportation, urbanization and overcrowding of roads, pollution in general, depletion of local non-renewable resources.

The sector that mostly suffers the consequences of this situation is agriculture which is the capacity of humans to stimulate and intensify the natural capacity of the land to give food and materials in exchange of solar energy. It plays a very important role in the economy of Province of Modena, with its typical products such as cherries from Vignola, Lambrusco wine from the districts of Castelfranco, Carpi, Modena and Mirandola, the unique balsamic vinegar from Modena and many others.

A very interesting development of this study would be a comparative analysis of the Italian (Sassuolo) and Spanish (Castellon de la Plana) ceramics productions and their effects on the environment, since they are two of the main industrial poles in Europe and both have important agricultural productions in nearly areas, i.e. citrus crops of Castellon de la Plana.

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