Int. J. Environ. Res., 3(2):301-308, Spring 2009
ISSN: 1735-6865

Environmental Impacts of Reconstruction Activities: A Case of Lebanon

Nasr, D.[1], Massoud, M.A.[2*], Khoury, R.[1] and Kabakian, V.[3]

[1] Earth Link and Advanced Resources Development (ELARD), Lebanon
[2] Department of Environmental Health, Faculty of Health Sciences, American University of Beirut, Lebanon
[3] Lebanese Ministry of Environment, Lebanon

Received 4 Oct. 2008; Revised 15 Dec. 2008; Accepted 3 Jan. 2009

ABSTRACT: Significant damages incurred across Lebanon during the July 2006 war encompassing the destruction of road networks, bridges and overpasses as well as a vast number of dwelling units. It is anticipated that reconstruction works after the war shall unavoidably create a newly founded demand for natural resources, most notably primary and secondary construction material. This paper assesses the war-related impacts of the construction sector on the environment coupled with recommendations for controlling and mitigating these impacts. A cost benefit analysis of four different scenarios for supplying construction material was conducted based on their environmental and fiscal costs as well as their economic benefits and government returns. The Fixed Box Model was applied to estimate air pollutants concentration. Results indicated that the preferred alternative for the supply of cement primarily consists of local manufacturing of 100 percent of the required quantities. With regards to sand and aggregates, the analysis indicated that the preferred alternatives are to either rely on local production or import 25 percent of the required material. The predicted average concentration of Total Suspended Particulates at the southern suburb of Beirut site exceeded the recommended values of the Lebanese, EU, USEPA, and WHO standards.

Key words: Reconstruction, Environmental Impacts, Air Pollution, Resources Depletion, Lebanon

INTRODUCTION

Management of debris is a major concern after any natural disaster or war resulting in a large burden on natural resources and an economically and environmentally costly solid waste disposal problem (Luther, 2008; Rafee *et al.*, 2008). In addition, reconstruction projects typically generate large volumes of waste material. Traditionally, most construction and demolition waste had been land-filled together with municipal solid waste (USEPA, 1995a). Given the enormous amount of space required to dispose of construction and demolition waste, decision makers and waste producers are progressively finding new methods to divert waste from landfills (USEPA, 1995; Duran *et al.*, 2006; Weil *et al.*, 2006). Construction works are among the main consumers of natural resources and energy over and above generating vast amounts of material waste (Ekanayake and Ofri, 2000; Chen *et al.*, 2005). Moreover, construction activities often result in surface and ground water contamination, soil contamination, atmospheric emissions as well as noise pollution (Shen and Tam, 2002; Cheng *et al.*, 2006; Ding, 2007; Gangolells *et al.*, 2007).

In Lebanon, management of solid waste has been a chronic problem, particularly in areas with high population density, high production of refuse, and low availability of land adequate for landfills (Massoud *et al.*, 2003). Accordingly, war-related impacts of the construction sector on the environment are noteworthy. The extent of damage is not only limited to the direct consequences of the war such as destruction of

*Corresponding author E-mail: may.massoud@aub.edu.lb

infrastructure, emissions of dust and particulates, release of potentially hazardous materials, generation of demolition debris and associated visual intrusion. Other indirect environmental impacts associated with the various stages of the construction chain, such as an incremental demand for quarrying products, a rise in the manufacturing of building material, in addition to a foreseeable increase in polluting reconstruction works are remarkable. This paper presents an assessment of the July 2006 war-related impacts of the construction sector on the environment coupled with recommendations for controlling and mitigating these impacts. It focuses on the impacts related to air pollution from increased dust emissions in construction sites and the predicted impact on Lebanon's natural resources.

The collective damages incurred across Lebanon during the July 2006 war consist of the destruction of approximately 445,000 m^2 of road network, 92 bridges and overpasses, as well as the destruction or damage of an estimated total of 130,000 dwelling units (HRC, 2006 Table 1). A study by the Economic Support Center (ESC, 2006) estimated the damage of transportation infrastructure to reach approximately 4,000,000 m^2. A total of 151 roads were reported to be damaged (PCM, 2006). Accordingly, the cost of reconstruction was calculated to be no less than USD 2 billion based on an assumption of USD 450-550/m^2 for reconstruction and debris clearance. In addition to the destruction of dwellings and transportation infrastructure, public utilities, such as water distribution networks, as well as public institution building structures were damaged. These damages were estimated to reach approximately USD 74 million (GoL, 2006). Primary inspections have estimated the rubble generated from the southern suburb region of the city Beirut at approximately 1 million m^3 (OCHA/ UNEP, 2006). Based on typical Lebanese civil works, and assuming the heavy damage or total destruction of 60,000 housing units (HRC 2006), industry experts estimated that approximately 1.8 million m^3 of rubble is scattered throughout the war-impacted villages of South Lebanon. Accordingly, the total volume of rubble is estimated to be within the range of 2.5 to 3 million m^3. Although the Higher Relief Council (HCR) contracted the rubble clearance works in all Lebanese regions (PCM, 2006), post-war initiatives also consisted of collaboration between the private and public sector. Several local municipalities contracted private sector haulers to transport and dump the waste in haphazard locations. The popular choice of dumpsite was empty lots, or in many cases inconspicuous valleys and ravines.

Table 1. List of the major damages to the construction sector (HRC, 2006)

Description	Quantity
Residential Infrastructure	
Private houses/ apartments (destroyed)	30,000
Private houses/ apartment (major damage)	30,000
Private houses/ apartment (minor damage)	70,000
Transportation Infrastructure	
Airports	3
Sea port	4
Roads (445,000 m^2)	151
Bridges and overpasses	92
Commercial Infrastructure	
Commercial sector (factories, markets, farms, medium size enterprises)	900
Small-size enterprises	2800
Public Infrastructure and Utilities	
Government institution (buildings)	66
Schools (destroyed or damaged)	350
Hospitals (major damage)	2
Health care buildings (destroyed or severely damaged)	50
Power plants / generation stations	15
Water distribution network (main and secondary)	330
Water dam	1
Sewage treatment plant	1
Sewage disposal systems (main and secondary)	158

Recently, the Ministry of Public Works and Transport executed three contracts for rubble removal in the South, while the Council for the South is executing the rest of the contracts (PCM, 2006). As for the rubble generated from the southern suburb of Beirut, a government based initiative, headed by the Ministry of Public Works and Transport called for the transport of the demolition debris to two major temporary storage sites located within the Greater Beirut Area, prior to disposal. The plan sanctioned by the government consists of segregating and processing the waste at these temporary storage sites prior to disposal for sea reclamation (CoM, Decision 91/2006). The direct damage of the war on the construction sector is obvious due to the destruction of building structures and generation of demolition waste. However, given the nature of the construction industry, the impact shall be extended to other stages of the construction process, namely the extraction and manufacture of building materials, the construction works, and building occupancy and maintenance.

MATERIALS & METHODS

Reported data and documentary analysis focusing on published government statistics, documents and annual reports, and academic literature were examined. Interviews were conducted with responsible authorities and individuals representing a cross section of key decision-makers or influential stakeholders. The compilation of the limited primary and secondary data on the direct damages of the July 2006 war was followed by an analysis of the environmental impacts, primarily in relation to natural resources depletion and air pollution. A cost benefit analysis of four different scenarios to mitigate the impacts of quarrying for cement production (Table 2)and for sand and aggregate production was conducted based on their costs (environmental and fiscal) and benefits (economic and government returns). To estimate air pollutants concentration, the Fixed Box Model was applied.

RESULTS & DISCUSSION

The major direct war-inflicted impacts of Lebanon's construction sector on the environment include dust emissions from bombardment, generation of demolition debris, physical harm of underlying flora and fauna and blockage of water ways as a result of demolition waste. The main indirect impacts include but are not limited to:

- Extraction of raw materials leading to natural resources depletion.
- Pollution from reconstruction works (dust emissions, soil erosion, water pollution, and construction waste generation).
- Building occupancy and associated energy and water consumption.

Construction works typically consume a large portion of natural resources such as water, energy, and mineral products.Accordingly, the vast reconstruction works after the July 2006 war shall unavoidably create a newly founded demand for natural resources, most notably primary and secondary construction material. Actually, it is estimated that the rebuilding of the 60,000 dwelling units that were reported to be completely destroyed or highly damaged (HRC 2006), would require approximately 3.5 million tons of sand and aggregates, 1.2 million tons of cement, and 0.22 million m^3 of water. In addition, the aforementioned buildings had generated an estimated 2.5 - 3 million m^3 of demolition waste (HRC, 2006).

Table 2. Cost to benefit analysis of the alternative scenarios to mitigate the impacts of quarrying for cement production and for sand and aggregate production

	Local Resources	External Resources	25 percent Local, 75 percent Foreign	25 percent Foreign, 75 percent Local
Cement production				
Costs (Mil USD)	716.73	142.06	285.73	573.06
Benefits (Mil USD)	75.92	67.68	232.24	561.36
B/C	**1.01**	0.48	0.81	0.98
Sand and aggregate production				
Costs (Mil USD)	1234.67	19.67	323.42	930.92
Benefits (Mil USD)	720.43	1.97	181.58	540.81
B/C	0.58	0.10	0.56	**0.58**

This incremental demand will possibly be met with an uncontrolled increase in local mining and quarrying activities leading to irreversible impacts on Lebanon's fragile environment. These impacts encompass the destruction of vegetation and natural habitats, permanent loss of biodiversity, increase in the levels of noise, visual and air pollution, pollution of groundwater and surface water resources, soil erosion, as well as associated loss of real estate value. Based on a study conducted by the World Bank, the annual costs of the environmental degradation caused by the quarry sector in Lebanon were estimated at 0.1 percent of the Gross Domestic Product (GDP) (Sarraf *et al.,* 2004). Importing all the required construction materials could be the best solution to avoid the impact on Lebanon's natural resources. However, this might affect the country's economic development as the construction industry constitutes approximately 7 percent of Lebanon's GDP (MoI, 1999).

With regard to cement production, Lebanon produces about 4.3 million tons annually with domestic demands in 2003 amounting to 2.7 million tons (Yager, 2004). Exports, as indicated by the Lebanese Customs Authorities, approached 1.6 million tons in 2005, while imports were negligible. Thus, it can be assumed that the incremental demand for 1.25 million tons of cement can be satisfied by the current production levels without any additional exploitation of natural resources. However, a more in-depth analysis of the cement market indicates a steep increase in the future domestic demand. In fact, according to an industry quarterly report by Bank Audi, the demand for cement in the construction industry increased two fold from the first quarter of 2005 to that of 2006 (Bank Audi, 2006). There is a considerable possibility that due to the predicted increase in domestic demand for cement, the reconstruction works may lead to increased quarrying for cement production.

Lebanon produces about 3 million m^3 of aggregates and sand annually (CAS, 2006). Data published by the Lebanese Customs Authority indicated that imported aggregates in 2005 reached 0.77 million tons, while exports were negligible. However, over the last few years, the quarrying sector has been subject to administrative changes concerning operating permits which has lead to significant variations in the levels of domestic production and importation. An overview of the sector indicates a predicted 73 percent increase in domestic quarrying activity to satisfy the war-related demand of an additional 3.5 million tones. A cost benefit analysis of four different scenarios was conducted based on their costs (environmental and fiscal) and benefits (economic and government returns). These scenarios include:

- Domestic supply of 100 percent required material.
- Importation (external supply) of 100 percent required material.
- Domestic supply of 25 percent of material and importation of 75 percent.
- Domestic supply of 75 percent of material and importation of 25 percent.

Results indicated that the preferred alternative for the supply of cement primarily consists of local manufacturing of 100 percent of the required quantities. With regards to sand and aggregates, the analysis indicated that the preferred alternatives are to either rely on local production or import 25 percent of the required materials. A summary of the cost to benefit analysis of the different alternatives for cement production and for sand and aggregates production is presented in (Table 2).

Large construction sites are significant sources of air pollutants. Building demolition, mechanical work processes (grinding, drilling), debris dumping and storage, and diesel engines powering construction machines can cause adverse health impacts as a result of airborne dust. In Lebanon, a substantial number of dwellings and houses are to be reconstructed after the war as presented earlier. The large number of construction sites, particularly in residential areas, is considered a major source of air and noise pollution. Emissions during the construction of a building or road can be associated with land clearing, drilling and blasting, ground excavation, and cut and fill operations. The emissions of dust often vary from day to day, based on the level of activity, the specific operations, and the existing meteorological conditions. A large portion of the emissions results from equipment traffic over temporary roads at the construction site.

The composition of ambient particulate matter is of homogeneous nature, comprising particles of various size and chemical composition. While physical properties of these particles affect the transport and deposition in the human respiratory system, chemical composition determines their impact on health. Suspended particulate matter is ubiquitously recognized as the most important air pollutant in terms of human health effects considering that many epidemiological studies substantiate significant associations between particulate matter (PM) concentrations in the air and adverse health effects (El-Fadel and Massoud, 2000). While the effects of PM vary considerably depending on its composition and size distribution, generally, exposure to inhalable PM can cause an increase in cardiac and respiratory mortality, a decrease in levels of pulmonary lung function in children and adults with obstructive airways disease, an increase in daily prevalence of respiratory symptoms in children and adults, an increase in functional limitations as reflected by school absenteeism or restricted activity days, and an increase in physician and emergency department visits for asthma and other respiratory conditions (El-Fadel and Massoud, 2000). Sensitive groups that appear to be at greater risk for particulate pollution include the elderly, those with pre-existing respiratory conditions and cardio-pulmonary diseases such as asthma, smokers, and children.

Considering that construction activities are temporary, have a definable beginning and an end and vary substantially over different phases of the construction process, the estimation and control of their emissions differs from other fugitive dust sources (USEPA, 1995b). Hence, the quantity of dust emissions from construction operations is usually proportional to the area of land being worked and to the level of construction activity(Table 3).Emissions from heavy construction operations are positively correlated with the silt content of the soil (particles with a diameter less than 75 µm), as well as with the speed and weight of the average vehicle, and negatively correlated with the soil moisture content. The approximate emission factor for construction activity operations (E) can be used as 0.3 kg/m^2/month of activity (USEPA, 1995b). This value is most applicable to construction operations with a medium activity level, moderate silt contents, and semiarid climateApplying this equation to the case of southern suburb of Beirut, assuming construction activities will last for 18 months, considering 30 days/month and 8 hours/day of work, this would lead to a temporal emission factor (S) equal to 347.2 µg/s.m^2. To estimate air pollutant concentration, a Fixed Box Model is applied whereby the site is represented by a parallelepiped(Table 4, Fig.1).

Table 3. Dust-generating activities in the different phases of construction (USEPA, 1995b)

Construction Phase	Dust-generating Activities
Demolition and debris removal	1. Demolition of buildings or other obstacles such as trees, boulders, etc.
	2. Loading of debris into trucks
	3. Transporting the debris
	4. Unloading of the debris
Site Preparation	1. Bulldozing
	2. Unloading topsoil by scrapers
	4. Removing topsoil by scrapers
	5. Loading of excavated material into trucks
	6. Dumping of fill material or any other material
	7. Compacting
General Construction	1. Vehicular traffic
	2. Portable plants
	a. Crushing
	b. Screening
	c. Material transfers and other operations

Table 4. Input data for the box model

Parameter	Typical Scenario	Worst-case Scenario
L*	200 m	200 m
H	1,000 m	100 m
b**	166 µg/m^3	166 µg/m^3
u	3.25 m/s	1 m/s
S	347.2 µg/s.m^2	347.2 µg/s.m^2

* Based on dimensions of the southern suburb of Beirut site

** Average TSP concentration in Beirut (El-Fadel and Massoud, 2000)

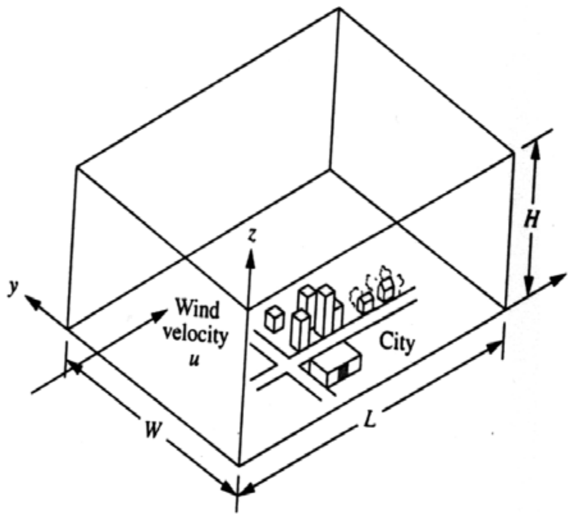

Fig. 1. Rectangular City in a Fixed Box Model

The following simplifying assumptions were made:

- Mixing of pollutants occurs within a layer of height H, confined from above by a layer of stable air;
- The concentration of pollutant in the entire area is constant and uniform, and equals to c;
- The wind velocity is constant and independent of time, elevation, and height above the ground;
- The concentration of pollutant entering the city (at x = 0) is constant, and equals to the base line measured Total Suspended Particle (TSP) concentration, b
- No pollutant enters or leaves the top of the box, nor the sides that are parallel to the wind direction;
- The destruction rate inside the box is zero.

The concentration of TSP in the entire area can be estimated using equation 1 (De Nevers, 1999):

$$c = b + \frac{SL}{uH}$$

Where:

c = Concentration of TSP in theentire site (μg/m^3)
b = Background TSP concentration (μg/m^3)
s = Emission rate of TSP (μg/s.m^2)
L = Site length (m)
H = Mixing height (m)
u = Wind speed (m/s)

CONCLUSIONS

The July 2006 war in Lebanon has lead to significant damage to the construction sector. Reconstruction activities are likely to generate various types of environmental impacts related to the management of demolition wastes, pressure on natural resources and air pollution in construction sites. Although reconstruction efforts will require substantial amounts of raw material, including cement, gravel, sand and water, these can be secured locally without causing significant impacts given that an adequate plan is prepared to organize quarrying activities. Green building alternatives ranging from simple no-cost building practices to complex and costly solutions can be implemented by the construction sector so as to maximize energy savings, minimize water consumption, improve the comfort, health, and safety of building occupants, and limit the detrimental effects of reconstruction works on the environment. Such measures provide both economic and environmental gains.

In Lebanon, green building standards for site planning and design, energy and water consumption, materials and waste management, as well as indoor air quality are not being applied due to a variety of reasons. Foremost amongst these reasons is the lack of a solid legal framework to stipulate such requirements. Other reasons include but are not limited to the absence of general awareness coupled with public disregard of the economic and environmental benefits of green construction. Moreover, practical experience of field professionals in the implementation of sustainable building practices is very limited. The recent Lebanese conflict can serve as an opportunity to incorporate sustainable green building standards in the reconstruction of the war-ridden regions of Lebanon as an initial step prior to incorporation within all future construction works.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support of the United Nations Development Program of this research study that was conducted in Lebanon by Earth Link and Advanced Resources Development (ELARD)

s.a.r.l in coordination with the Lebanese Ministry of Environment.

REFERENCES

Bank Audi. (2006). Lebanon Economic Report - Facing the Critical Challenge of Restoring a Lost Confidence, 2nd Quarter Report.

CAS (Central Administration for Statistics of Lebanon). (2006). Compendium Statistique National sur les Statistiques de l'Environnnement au Liban 2006, MoE, EU/Eurostat.

Chen, Z., Li, H. and Wong, C.T.C. (2005). EnvironalPlanning: analytic network process model for environmentally conscious construction planning. *J. Constr. Eng. Manage.*, **131(1),** 92–101.

Cheng, E.W.L., Chiang, Y. and Tang, B. (2006). Exploring the economic impact of construction pollution by disaggregating the construction sector pf the input-output table. *Build. Environ.*, **41(12),** 1940-1951.

CoM. (2006). Decision 91/2006, on the Identification of a Site within GBA (Solidere) for the Disposal of Rubble Generated from the Dahieh. Council of Ministers of Lebanon.

De Nevers, N. (1999). Air Pollution Control Engineering. Singapore: McGraw Hill Science Engineering.

Ding, G.K.C. (2008). Sustainable construction: The role of environmental assessment tools. *J. Environ. Manage.*, .**86(3),** 451-464.

Duran, X., Lenihan, H. and O'Regan, B. (2006). A model for assessing the economic viability of construction and demolition waste recycling - the case of Ireland. *Resour. Conser. Recycl.*, **46,** 302-320.

Ekanayake, L. and Ofori, G. (2000). Construction material waste source evaluation. *Proceedings: Strategies for a Sustainable Built Environment, Pretoria, 23-25 August 2000.*

El-Fadel, M. and Massoud, M. (2000). Particulate matter in urban areas: Health based economic assessment. *Sci. Tot. Environ.*, **257(2-3),** 133-146.

ESC. (2006). The Lebanese Losses Resulting from the Israeli Attack on Lebanon. Economic Support Center for Private Sector Establishments Report 11/06 FS/AM.

Gangolells, M., Casals, M., Gassó, S., Forcada, N. and Roca, X. (2007). A methodology for predicting the magnitude of environmental impacts related to the building construction process. In: Proceedings of the CIB World Building Congress on construction for development, **1,** 2441–9.

GoL . (2006). Setting the Stage for Long Term Reconstruction: The National Early Recovery Process, Stockholm Conference for Lebanon's Early Recovery. Government of Lebanon.

HRC. (2006). Daily Situation Report SITEREP No. 78, Posted on official government website: http://www.lebanonundersiege.gov.lb. Higher Relief Council of the Government of Lebanon.

Luther, L. (2008). Disaster Debris Removal after Hurricane Katrina: Status and Associated Issues. CRS Report for Congress, Order Code RL33477.

Massoud, M., El-Fadel, M., & Abdel Malak, A. (2003). Assessment of public vs. private MSW management: A case study. *J. Environ. Manag.*, **69,** 15-24.

MoI. (1999). Action Plan for the Development of the Lebanese Industry. Ministry of Industry of Lebanon.

OCHA/UNEP. (2006). Environmental Update No. 03 - Lebanon Crisis. United Nations Office for the Coordination of Humanitarian Affairs/United Nations Environment Program.

PCM. (2006). Lebanon: On the Road to Reconstruction and Recovery - A Periodic Report published by the Presidency of the Council of Ministers on the post-July 2006 Recovery and Reconstruction Activities - First Issue. Presidency of the Council of Ministers of Lebanon.

Rafee, N., Karbassi, A. R., Nouri, J., Safari, E. and Mehrdadi, M. (2008). Strategic Management of Municipal Debris aftermath of an earthquake. Int. J. Environ. Res., **2(2),** 205-214.

Saraf, M., Owaygen, M. and Larsen, B. (2004). Cost of Environmental Degradation - The Case of Lebanon and Tunisia. Environmental Economics Series, Paper no. 97, The World Bank.

Shen, Y. and Tam, V.W.Y. (2002). Implementation of environmental management in the Hong Kong construction industry. *Int. J. Project Manage.*, **20(7),** 535–543.

USEPA. (1995a). Construction and Demolition Waste Landfills. USEPA, Office of Solid Waste. United States Environmental Protection Agency.

USEPA. (1995b). Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources.

AP-42, 5th ed. USEPA, Office of Air Quality Planning and Standards. United States Environmental Protection Agency.

Weil, M., Jeske, U. and Schebek, L. (2006). Closed-loop recycling of construction and demolition waste in Germany in view of stricter environmental threshold values. *Waste Manage. Res.*, 24, 197-206.

Yager, T. (2004). The Mineral Industry of Lebanon, United States Geologic Survey (USGS) Accessed at: http://minerals.usgs.gov.