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Nutrient balance Model of Urban Emissions in the Northern Litani River Basin

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Abstract
High population density, high exchange rates of products and goods, vital dependence on sources and deflection of energy and matter beyond their settlements borders have been the contemporary idiosyncrasies of urban culture. In Litani region, population density has changed increasingly from about 800/km^2 in 1980 to more than 2150/km^2 in 1998.The canalization of sewage water from households and industries leads to severe chemical pollution of surface and groundwater. The exponential growth of population was accompanied by acceleration of urbanization and an increased demand for water, energy and food. This situation pushed citizens to overexploit natural resources. The populations in the catchment area (before Qaroun dam in the Litani River) produce 16.1 Mm^3 of wastewater/year with total emissions of BOD, COD, N, and Pare 5215.5, 12673, 1365, and 167 tones/year respectively. In addition, these residents produce 88578.368 tons/year of solid wastes (60% organic content). As the moisture of domestic wastes is about 70%, that contain 653.25 tN/year (tones of nitrogen) and 125.3 tP/year (tones of phosphorus) as well as 248,200 Kg / year of medical wastes. We introduced the results through an ecological model for the urban emission in Litani River Basin. This proposed model can provide encouraging results and might be used as an efficient tool to identify the effect of households' and pollution sources for planning and management of large-scale River catchment.

Keywords: Urban emission, nutrient balance, modeling, Litani River, private houses pollution, and Basin

Introduction

Urbanization

The contemporary idiosyncrasies of urban culture are high population density, high exchange rates of products and goods, vital dependence on sources and sidetrack of energy and matter.

As population increased, the rate of interaction between the environmental compartments will increase leading to more deterioration in natural sources. In Lebanon, throughout 54 years (1936-1990), population density had increased 100%. In Litani region, particularly, Zahle city has a rapid rate of change in population density from an estimated 800/km^2 in 1980 to exceed 2150/km^2 in 1998.

The industrial and hazardous municipal solid wastes, which were estimated by 80 kg/capita in 1983, considered as the most important carrier of chemical energy and various metals.

As urban areas expand, the basic necessities for life such as water became unavailable in proper quality and sufficient quantity. Urbanization has produced a high density of energy and material.
Urban regions have become increasingly as a less uniform system regarding supplying energy, utilization of goods and data distribution. This evolution in the socio-economic system is also observed in Lebanon:

1- Large network of roads, highways and railroads even though its relatively small area (10452 km²). Due to the availability of public and private transport means between cities and rural areas, we don't observe migration of large amount of people from countryside to cities. So, the expression "Let's go to the city" is still limited.
2- The development of the socio-economic system in Lebanon is accompanied by a 15 year (1975-1991) civil war, with full absence of law and constitutionalism, where citizens used the natural resources and destroyed some natural ecosystem without any care or control.

Private household compartment acquires goods (flux 'sale') and releases them (flux waste after consumption). These goods have different residence intervals within the compartment (reservoir 'stock') during "consumption". A short-lived product as detergent, is normally used within days to weeks, this output of waste water is rich with phosphate that can affect the nutrient balance of the system and causes eutrophication in surface water.
Strong impact on environment due to high residual fluxes dissipated into the main compartments of the natural capital. The impact of the residual materials fluxes may return to air from the natural systems, where the aquatic and terrestrial ecosystems could have a fatal effect on man earlier than it was thought before.

Litani River basin:

Figure 1: Location of Lebanon.

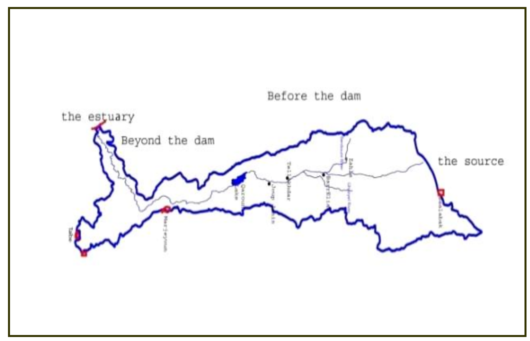

Figure 2: Litani River catchment area.

Litani River as the longest Lebanese river (170km long) has a catchment area of about 2,175 km² representing about 20% from the total area of Lebanon (10,452km²), and having an average discharge of 20 m³/sec (630 mm³/year) (Fig 1).
This catchment area can be divided into two parts (Fig 2): first,the northern part from spring till the dam of the Qaroun Lake, covering a large part of the middle and southern part of the Beqaa valley (about 1,300 km²). Second, the southern area,the (South Lebanon) and a portion of the coastal region are included with surface area around 875 km².

Table 1

Distribution of Population by Mohafaza (1997)

Mohafaza	*Population*	*Percent*	*Surface Area (km^2)*	*Population Density*
Beirut	403,337	10%	20	20,167
Beirut Suburbs	899,792	22%	233	3,862
Rest of Mount Lebanon	607,767	15%	1,735	350
North	807,204	20%	2,025	399
Bekaa	539,448	13%	4,161	130
Nabatieh	275,372	7%	1,098	251
South	472,105	12%	930	508
Total	**4,005,025**	**100.0**	**10,202**	393

Source: CAS Study, No. 9/1998

Demography

More than 200 villages and cities (almost 700,000 individuals) depend on this river's water for drinking and domestic use.

Lebanon is divided into six administrative divisions, governorates (table 1),called *Mohafaza*t, which are sub-divided-except Beirut- into 25 districts, called *Akdiya*. Each district is made up of several cadastral zones, *ManateqEkariah* (1,492 zones). Bekaa, where Litani River is found, is the largest governorate (4,161 km²).

Since the last survey for population done in 1932, nocensus has been achieved on the actual size of the Lebanese population. Central Administration for Statistics (CAS) has estimated Lebanon's population (within the country)nearly 4 million in 1996-1997(CAS 1998).Population size is growing at the rate of 1.65 percent yearly – about 66,000 net births in 1999 (CAS, 2000). Average life expectancy is 71.3 years (MoSA, 1996).

Giving the estimations of CAS and MoSA, we can deduce that the population in the Litani catchment area is approximately 750,000 persons. Based on different sources and data, many studies were done by different NGOs to evaluate the total number of dwellers in the catchment area of the river on the northern part of the Qaroun Lake.Residents in this area were estimated by roughly 310,000 individuals (FredrishEapert Corporation, 1994), while that in the southern part of Litani River catchment area were estimated around 450,000 populaces in 1981 (Ali Faour, 1985).

As we have mentioned before, nearly 20% of the Lebanese population are living in the catchment area of the Litani River system (Fredrish Eapert Corporation, 1994). In particular, urbanization, advertisement, low and medium tension power lines, quarries and roads affect the landscape.

Litani River's catchment area is formed of about 150 assemblages of cities, villages and farms in both, northern and southern part of the Qaroun dam, 70 and 80 respectively (MoIA, 1991).

Population size in the Litani River region is high in large cities, such as Baalbeck and Zehle, as well as along Beirut-Damascus international highway in QebElias. (*National Center for Remote Sensing and CERMOC)*

Different researchers and institutions calculated the sewage rate in the region as 120 liters daily per capita by using various ways and tools (SOER, 1995)whereas the official one is 160 L/capita/day (MOE, 2001).Rates may vary(e.g., Baalbeck) from 100 to 200 L/capita/day. A lot of water is additionally supplied from private wells and ultimately ends up in the sewage flow.

Based on the estimation of population projection in 2001 (for Lebanon), the total wastewater flow is estimated at 249 mm^3/year ($8m^3$/sec), higher than 163 mm^3 in 1995 (5.2 m^3/sec). Assuming that BOD load is 400 mg/l in raw sewage, yearly outflow results in a BOD load of 99,690 tons, as compared to 65,300 tons in 1995.

The daily use of water per capita was estimated at 165, 215, and 260 L in 1990, 2000, and 2015 respectively (MKGI and CAMP DRSER Company, 1982). Giving this value, the quantity of water from Litani River water stream that was used in 1990 by the residents of the area under study is:

165 liter x 750000 person =115500 000 liter/day~ 42.157Mm^3 /year.

Lebanese Ministry of Agriculture (MoA) expects that the percentage of pollution in the surface water by 2020 would increase to exceed 70% (MKGI and CAMP DRSER Company /1991).

In a report, published in 1994 by Fredrish Edbert, it was estimated that 50% of the population in the Litani River basin have access to a sewer system, 42% rely on septic tanks and 8% use primitive means to dispose sewage system. Add to this the time wornsewer systems that serve both households and industries in the area.

Septic tanks are not considered as treatment devices for sewage where tanks overflow consequently, and the result the uncontrolled discharge of wastes. This mean proposes many problems during heavy rain, especially on groundwater.

Knowing that animal and human feces contaminate the aquatic system by many kinds of bacteria and viruses that cause different diseases (Mona Jradi, 1996), testing some samples of Litani River stream and Qaroun Lake revealed the presence of Enterobacteria (Arizona bacteria), Coli forms (E-coli), and Salmonella (Public Health Ministry/1996).

Arizona bacteria were found too in the dead fish's samples taken from Qaroun Lake (Public Health Ministry/1996). These results confirm the contamination of the river water with animal manure.

Lebanese community produces 3 kinds of solid wastes and garbage: domestic and house wastes, sanitary or medical wastes and butchery wastes.

A report published by The Building and Development Council in the Lebanese government /1998 (Sida, Asdi, 2000), stated that "The daily products of garbage per person is about 0.8 kilogram, and the daily products of sanitary and medical wastes by one clinical bed is about 0.85 kilogram, while the slaughter houses produce about 30% of the consumed cattle weight as wastes".

If we consider that the number of residents in the Litani River area about 700.000, then they will produce 560.000 kg of domestic wastes and garbage every day. Butchery and medical wastes, unfortunately, have not been monitored by any individual or institution, but the traces of these kinds of wastes are very clear in the surrounding area of the river system under study.

Studies indicate the presence of heavy metals produced from solid wastes (urban and industrial wastes) which are discharged toward the water courses of the rivers in a direct or indirect way. The impact of hydrocarbons and chlorinated organic substances from the waste site is presented also.

Deforestation, either for building or for charcoal purposes, decreases the amount of forests in Lebanon by more than 20 % in the last two decades.

Methodology

In order to evaluate the environmental quality of the Litani river region, I took water samples, sediments, soil and wastewater samples.

The sampling were established in order to cover the heterogeneity of the catchment and to observe the 'hot spots' and point sources of nutrient emission and other pollutants according to the available information.

Table 2: parameters of sample testing.

Type of Samples	Parameters
Industrial wastes	Flow rate, pH, conductivity, total N, nitrates, ammonia, total phosphorus, ortho-phosphorus, COD, BOD, Cr, Mn, Fe, Cu, Zn, Cd, Pb, Hg.
Wastewater	% of sewer for each village, flow rate L/sec, COD
Sediments of the river	Cr, Mn, Fe, Cu, ZN, Cd, Pb, Hg,
Soil	PH, conductivity, oxidized organic carbon, organic matter, nitrates, total phosphorus.
Recipient water of Litani River	conductivity, pH, total phosphorus, ortho-phosphorus, nitrates, ammonia, COD, BOD, Cr, Mn, Fe, Cu, Zn, Cd, Pb, Hg.
Water samples from Qaroun Lake.	Chlorophyll a, secchi test, Nitrate, ortho-phosphate

During testing, I used EPA approved methods performed for water and soil quality analyses.

By this, sampling program included:

1- Industrial wastewater near and inside industrial factories.
2- Municipalities and sewer wastewater.
3- Sediments from Litani River stream.
4- Soil samples in the region.
5- Water samples from Litani River.
6- Water samples from Qaroun Lake.

Each sample has been tested according to specific parameters, areused as indicators of the trophic state and other pollutants (Table 2).

Results

Raw (untreated) wastewater from various municipalities and industries within the catchment area is discharged into tributaries of the Litani River and the river itself without any treatment or control.

Great many villages in the region are not provided with a sewer system and they are still using septic tanks.

To evaluate the amount of nutrients and organic matter discharged by population through waste water, we considered Lebanese Management Waste Water Plan (LWWMP, 1982) estimations for population water consumption (150l/capita/day). So, each person emission coefficient is 55 kg of COD/capita/day and a mean value of 400 mg BOD/l in raw wastewater (LWWMP, 1982). For nitrogen and phosphorus emission coefficients, I based my calculations on residents' food consumption. As these statistical data were not available, either at the national or regional level, I considered a mean emission factor of 4.5 kg N/capita/year and 0.55 kg P/ capita/year, which are related to most countries in Europe.

Total emissions from population in this region are:

- 5215.5 tones BOD/year.
- 12673 tones COD/year
- 1365 tones N/year.
- 167 tones P/year.

However, the effect of these emissions on water quality in the region cannot be evaluated exactly where the way of emission is not known. Hence, data about population (connected or not connected) to the sewer system is crucial for the evaluation.

The gathered data during my field trips showed51% of the settlements contain 69% of the population connected to a sewer network. Population in these settlements increased from 200,100 to 230,777 persons between 1994 and 2000 (with an increase about 16%). These people produce about 34,847m³/h of wastewater which is about 12.63 mm³ of wastewater/year. That contains about9389and 3851 tons of COD and BOD respectively.

According to the previous presented values for nutrient emissions, the amount of discharged nitrogen and phosphorus for the connected population in this region becomes 1038.5 tone N/year and 127 tones of P each year.

Populations, which are not connected to the sewer system, use the sewer black wells or septic tanks and the products are discharged to the soil. In this case, the impact on groundwater and soil as well is increased. On the other side, population not connected to the sewer system is 31% of the total population in the region (i.e. 72,577 persons). This population produces about 3.4 Mm³/year of wastewater and nearly3284,1364.5, 326.5, and 40 tons/ year of COD, BOD, N and P respectively.

Disposal sites in the northern part of the Litani river catchment area are identified. Conducting field investigations, I found that the sites are generally located in the proximity of rivers and watercourses. This leads to immediate release of leachate into water as well as to the pollution of rivers due to solid waste disposed.

There are no incinerations – except in Zahle- where wastes are burned in the fields. Burning causes serious air pollution, but decreases the impact of organic substances to the water recipients. The standards of the landfills in use are generally very low. None of the sites in use has any sealing to protect the soil and groundwater from leaching, and none of the sites has any facilities to collect and treat leachate. The soil in the proximity of the sites is contaminated. This contamination is important even in the abandoned sites and a potential hazard to the environment will be present for long time, unless measures are not taken to seal or clean the sites at a closure.

Some studies on the disposal waste site in Zahle, estimated that the impact on the Berdouni River is due to the following substances:gammahexachlorocyklohexan (γ-HCH), Alkyl-naphthalene, Alkyl-benzene, and xylenes.

The impact of solid wastes in the Litani River region can be estimated by calculating that each person produces about 0.8 kg of solid wastes every day (MoE, 2001), so we have about (0.8 x 303,354) 242,683.2 kg of solid wastes each day (88578.368 tons/year). The organic content of wastes is about 60%. As the moisture of domestic wastes is about 70%, it appears that the leaching is important as far as the landfills are not sealed, and the impact on ground water is also increased.

We measured the amount of N,P-fluxes in the population's wastewater in the Litani region (mean value) and it was found 1,365 tN/year and 167 tP/year.In order to get better estimations for these fluxes, we evaluated the nutrient loads of wastewater from population, the nitrogen and phosphorus emission factors were first calculated. We assumed that ~3% of nitrogen input is lost through perspiration and epidermal erosion (Baccini and Brunner, 1991), while about 15% of the nitrogen content of food went to solid waste. For phosphorus, a percentage of 10% was considered to be lost in the solid waste.

Therefore, the real N, P - emission factors we obtained are:

$5 \times 82/100 = 4.1$ kgN/inh/year

$0.6 \times 90/100 = 0.54$ kgP/inh/year

And the nutrient loads of wastewater have been calculated according to:

- N, P - load of wastewater = N, P - emission factor + N, P - load of supplied water + P from detergents
- N - load = 4.1 kg N/inh/year × 313,354 inh× 10^{-3} + 65.55 = 1,350.3 tN/year
- P - load = 0.54 kg P/inh/year × 313,354 inh× 10^{-3} + 1.55 + 8 = 178.8 tP/year

So, it is too close to our real data.

Table 3. Nutrient balances for Private Households in the Litani catchment, 2004.

Input fluxes into Private Households

Source	Good	N - fluxes (tN/year)	P – fluxes (tP/year)
Industry	Non-durable good	2,031.8	290
Water supply	Drinking water	65.55	1.55
Industry	Source of energy	?	?
	Total input	***2,097.45***	***291.55***

Output fluxes into Private Households

Good	Process of destination	N - fluxes (tN/year)	P – fluxes (tP/year)
Wastewater	WWM	1,350.3	178.8
Offgas	Troposphere	?	-
Municipal solid waste	Waste Management	653.25	125.3
	Total output	***2,003.75***	***304.1***

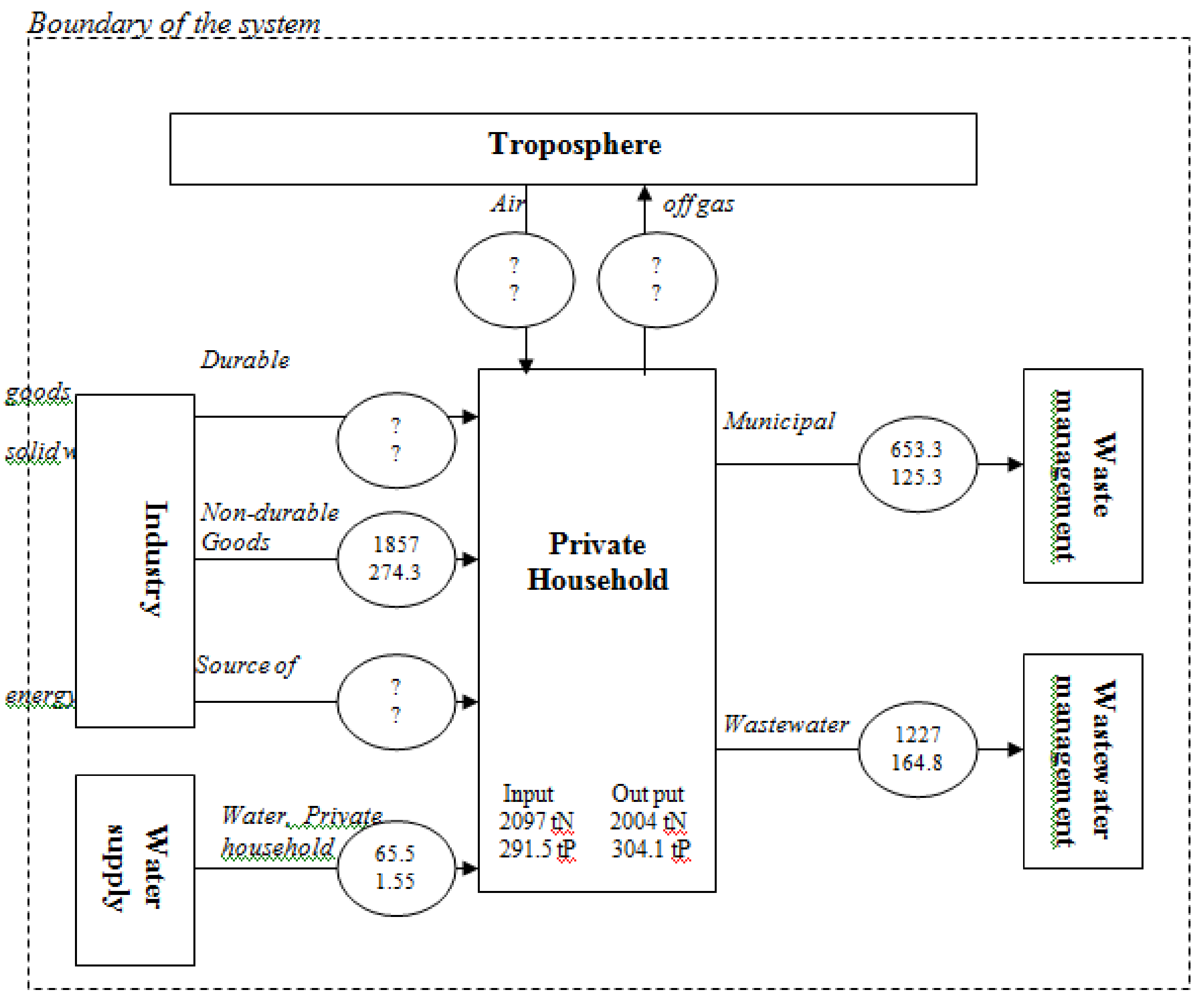

Figure 3: Nutrient balance for the process private household in Litani catchment (in t N-P/year) - 2004.

The municipal solid waste was considered to be formed by specific percentages of the nutrient input from food (15%), the N, P content of ~95% of the paper input. These account for about 653.25 tN/year (235+ 441.75) and 125.3 tP/year (28.2+ 89.3).

The balance between input and output fluxes is presented in Table 3 and figure 3.

The fluxes associated with energy sources could not be calculated due to the lack of data. Population mostly uses gas for heating but the amount is not known. Their input flux is normally balanced by the output of offgas, which was not assessed.

Conclusion

According to the results of influxes and the model of nutrients in the Litani River basin, we notice that a lot of wastes are discharged to the system without treatment, which will increase the emission of nitrogen and phosphorus, and the trophic level of the ecosystem from oligotrophic to eutrophic ecosystem which, in turn, will transported by water downstream to another ecosystem. Furthermore, a lot of sub compartments need studying in further details to deduce more information and data that can provide us with a real picture of the studied area.

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