# A Study for the Necessity of Risk Assessment for Heavy metal Pollution in the Barada Basin, Syria

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**Abstract:**

Huge amounts of heavy metals are being discharged from manufacturing industries to environmental media, particularly rivers in Barada Basin, carrying high risk to environment and human health. Few studies show that concentrations of chromium, cadmium, and lead exceed the standards in down streams of rivers.

In this paper, by developing a mathematical model that describes the interrelation between the ecological and economic systems, we run simulation to estimate amount of Cr, Cd, Pb generate from manufacturing industries annually under current economic condition. The results show that high concentration of these contaminants are discharged to rivers annually urging for risk assessment of these metals on environment and human health in further studies.

## 1. Introduction

Barada basin is the biggest human assembly in Syria. Thus, various socio-economic activities take place in the basin. Government policy enforcement to enlarge industrial investments leads to haphazard increase of the number of firms to satisfy the market demand beside random discharged of waste. All the industrial wastewater is discharged directly to environmental media without any kind of treatment. Beside the huge amount of organic pollution contaminate the water bodies, Barada and Awaj Rivers, considerable amount of heavy metals generated also from specific manufacturing such as, textile, chemical, and metal industries. That makes surface water pollution a severe problem in the basin [8] [20].

There are more than 12,000 factories ranked from micro-scale with one worker to large-scale firms with hundreds of workers belong to private and public sectors. Number of chemical, metal, and textile manufactories are approximately 40% of total factories but they produce huge load of heavy metals especially, chromium, cadmium, and lead. Chromium generate mainly from leather processing, metal calving and battery production. Moreover, cadmium is discharged from smelters, iron and steel plants, and battery production. While the main sources of lead are smelting, and processing of lead and lead-containing metal ores [11] [22].

Those industries usually assemble in urban areas in downstream of rivers. So they still keep upstream quite far from industrial pollution. However, downstream particularly

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the Barada River, is remarkably polluted. The most highly contaminated area that worth to be mentioned is the Zablatani tannery district in the eastern district of the city of Damascus. This area consists of several type of industries, but the most critically it includes a large cluster of tanneries. Leather processing is carried out in around 160 private tanneries and four public ones. The estimated wastewater described in table 1[20]. It obviously shows that significant pollution load is generated from this area much more that the allowable guideline for industrial wastewater to discharged to sewage network. It is important to notice the amount of untreated chromium discharged directly to environment is around 0.6t/day. The concentration of chromium in the wastewater reaches 100mg/l where the standard is 5mg/l. More than twenty times of allowable concentration go to river everyday. That situation urge for immediate action toward reducing this enormous amount of Chromium.

Table 1: Estimated Wastewater Discharges and Characteristics for tanneries in Zablatani[20]

| | Concentration(mg/l) | Mean Load(t/d) | Syrian standard to discharged to seweg(mg/l) |
|---|---|---|---|
| BOD | 1200-1500 | 16 | 1000 |
| COD | 3000-4000 | 43 | 3000 |
| TN | 430-1100 | | |
| TP | 6-16 | | |
| Chromium | 70-100 | 0.6 | 5 |

Besides, In 1998 the first sewage treatment plant in Damascus started operation. It is located at Adra, 20km east the city. The treated water are planned to use for irrigation for around 15,000ha through concrete canals [9]. The plant has good biological treatment but there is no special treatment for inorganic matters specially heavy metals. It is easy to guess the tragedy from such issue. First, these inorganic frequently cause malfunction of the plant, hence the wastewater are discharged lastly without any treatment, so often. That implies huge load of pollution released to final destination. Second, The treated water used for irrigation transmitting massive amount of heavy metals to plant tissues. Analysis undertaken by Ministry of Environment on the leaves of several plants shows that heavy metals exist in relatively high concentration (Table 2). That carries great impact on inhabitants and human health [22].

Table 2: Heavy metals in Plants' leaves[10]

| | Cadmium ( ppm ) | | Chromium ( ppm) | | Lead (ppm) | |
|---|---|---|---|---|---|---|
| | Peak | Typical | Peak | Typical | Peak | Typical |
| Corn | 0.038 | 0.032 | 1.9 | 1.8 | 2.1 | 1.72 |
| Lettuce | 0.1 | 0.07 | 8.7 | 4.6 | 0.6 | 0.26 |
| Mint | 0.36 | 0.12 | 13.05 | 7.4 | 0.24 | 0.09 |
| Parsley | 0.13 | 0.07 | 4.7 | 3.1 | 2.6 | 0.57 |
| Sorrel | 0.96 | 0.17 | 42.46 | 14.5 | 3.0 | 0.8 |

According to tested samples in the laboratory of municipalities affiliated to Ministry of Local Administration, Heavy metal does present in surface water, ground water and sediment. However, surface water samples show very high concentrations of Chromium, cadmium and then lead. These concentration is much over than WHO, Syrian for drinking water and FAO standard for irrigation, in the downstream, especially Barada River. It shows significant deterioration of Barada River water. Since sampling have been started in 1978, the concentration of chromium, cadmium and lead in crease 10-15 times. Fortunately, river water is not used for drinking water otherwise, outspread of water poisoning might have happened long time ago. The peaks detected were 40.39 mg/l for Cr, 0.506 mg/l for Cd, and 0.272 mg/l for Pb in 1998 at Zablatani, Damascus and Harasta, Norht Douma.

In this paper, we analyzed the problem from point-source of pollution. For this purpose, we develop a mathematical model based on Principle of Material Balance and optimization criterion to describe the behavior of pollutants dynamically in the environment on one hand and the market condition and its effects on environment on the other hand. For examining the interrelation between the two system, it involved estimating emission coefficients from each type of manufacturing using specific data and guidelines [18][21]. After that, simulation was run for 10 terms of time using LINGO software and the results are discussed to fulfill the paper objectives. By this simulation we could achieve the following:

1. Estimate the amount of specially serious heavy metals, Cr, Cd, Pb, generate from each type of manufacturing sectors,
2. Predict the effect of economic growth on increasing the load of pollution in long-term,
3. Study the contribution of pollution loads among districts in study area,
4. Determine the necessity of risk assessment of such metals on environment and human health in particular.

## 2. The model

We have developed model to analyze comprehensively the most critical pollutants in the study area including organic pollutants beside heavy metals for each activity in each zone. However in this paper the results focus only on heavy metals to correspond with the paper objectives.

### 2-1 The model variables and definitions

The study area includes the drainage basin of each The Barada River and The Awaj River.
Administratively, it includes two provinces, Damascus and Rural Damascus. The province of Rural Damascus affiliates six districts. Two of these districts are located in The Barada Drainage Basin, two are located in Awaj Drainage Basin and the other two lie on both basins as shown in table 3.

Table 3 Flow of water in the sub-district affiliated to both rivers[16].

| Province | District | Sub-District | Water flow |
|---|---|---|---|
| Damascus City | | | Barada River |
| Damascus Rural | Damascus Rural Center | Babilla | Barada River |
| | | Jaramana | Barada River |
| | | Erbeen | Barada River |
| | | Al-Kissweh | Awaj River |
| | | Kafar Batna | Barada River |
| | | Mleiha | Barada River |
| | Al-Tal | Al-Tal Center | Barada River |
| | | Rankus | Barada River |
| | | Sednaya | Barada River |
| | Darya | Darya Center | Awaj River |
| | | Suhnaya | Awaj River |
| | Douma | Douma Center | Barada River |
| | | Harran Al-Awamid | Barada River |
| | | Harasta | Barada River |
| | | Al-Dmir | Awaj River |
| | | Al-Nashabieh | Barada River |
| | | Al-Ghozlaniy | Awaj River |
| | Zabadani | Zabadani Center | Barada River |
| | | Dimas | Barada River |
| | | Serghaya | Barada River |
| | | Ain Al-Fijeh | Barada River |
| | | Madaya | Barada River |
| | Katana | Katana Center | Awaj River |
| | | Al-Haramoun | Awaj River |
| | | Saasa | Awaj River |

The study area contains ten zones nine of them are divided according to the water flow in the sub-districts to each river. There is single treatment plant for treating Damascus city wastewater, Adra treatment plant. The treated water is used for irrigation in zone 5 (Table 4).

Table 4: Classification of zones

| Zone Index | Zone |
|---|---|
| 1 | Zabadani |
| 2 | Damascus |
| 3 | Al-Tal |
| 4 | Damas-Rural |
| 5 | Irrigation project |
| 6 | Douma-North |
| 7 | Katana |
| 8 | Darya |
| 9 | Al-Kissweh |
| 10 | Douma-South |

In The Barada Drainage Basin zone 1, 2,3,4,5, and 6 are located. However, 1,2,5,6 only are located along the river. In The Awaj Drainage Basin zone 7, 8,9,10 are located but zone 8 is not located along the river. Zone 4, 9 are affiliated to same district and the same for zone 6, 10.

The industrial activities are classified as shown in table 5.

Table 5: The classification for industries

| Index | Industry |
|---|---|
| 1 | Agriculture |
| 2 | Food |
| 3 | Textile |
| 4 | Chemical |
| 5 | Metal and electric devices |
| 6 | Other manufacturing |
| 7 | Other |

The selected pollutants which are controlled in the simulation are as follows:

Table 6: The classification in the pollutants

| Index | Pollutant |
|---|---|
| 1 | TN |
| 2 | TP |
| 3 | BOD |
| 4 | Chromium |
| 5 | Lead |
| 6 | Cadmium |

**2-2 Model objectives**

1. Clarify the multi-sector interrelationships and determine the characteristic of ecosystem and socioeconomic structure in each zone [2].
2. Estimation of pollutant distributions in activities, particularly manufacturing and the chronic interrelation between production and pollution.
3. Estimation of pollutant distribution in zones
4. Maximizing the GRP as indicator of welfare in zones and examine the correlation ratio between amount of pollution and GRP in order to conduct the economic efficiency of an introduced policy in further steps of our research.

**2-3 Model specification**

Since previous studies shows that river water is the most polluted among environmental media beside the limitation of data, the model is restricted to interrelation between socioeconomic activities and pollution of rivers, neglecting the quality of ground water and sediment.

**2-3-1. Total pollution**

Based on Principle of Material Balance [4][5][6][7], the total pollution flows to each The Barada and Awaj Rivers is calculated by the pollution generates from each zone

$$TB_p^B(t) = TB_{1p}(t) + TB_{3p}(t) + TB_{4p}(t) + TB_{5p}(t) + TB_{6p}(t)$$
$$TB_p^A(t) = TB_{7p}(t) + TB_{8p}(t) + TB_{9p}(t) + TB_{10p}(t) \quad \ldots\ldots(1)$$

$TB_p^B(t)$: The total amount of pollutant p flowing to Barada River at time t.

$TB_p^A(t)$: The total amount of pollutant p flowing to Awaj River at time t.

In order to know which type of socioeconomic activity participate the most in the contamination discharged in each zone, the total amount of pollutants generate from each zone is calculated as follows:

$$TB_{ip}(t) = CI_{ip}(t) + CH_{ip}(t) \quad \ldots\ldots(2)$$

$CI_{ip}(t)$: The amount of pollutant p generates from total industrial activities in zone i at time t.

$CH_{ip}(t)$: The amount of pollutant p generates from households in zone i at time t.

$$CI_{ip}(t) = \sum_j e_{jp}^i Y_{ij}(t) \quad \ldots\ldots(3)$$

$$CH_{ip}(t) = e_{hp} P_i(t) \quad \ldots\ldots(4)$$

$TB_{ip}(t)$ : Total amount of pollutant p generated in zone i at time t.

$Y_{ij}(t)$: Total production of industry j in zone i in monetary term at time t.

$P_i(t)$: Population of zone i at time t.

$e_{jp}^i, e_{hp}$ : Emission coefficients to rivers of pollutant p for industry j (in zone i) and household respectively.

However, in zone 2 where Damascus City located the domestic and industrial wastewater is treated in Adra treatment plant using activated sludge. This biological treatment reduces BOD, TN, and TP but can not treat heavy metals carried by industrial wastewater. Those amounts of pollutants are calculated in the following equation:

$$TB_{2p}(t) = CI_{2p}(t) \quad \ldots\ldots(5)$$

while $p = 4,5,6$

Besides, in zone 5 the treated wastewater of Adra plant is used for irrigation so the total pollution generated is, in addition to the contamination generated from socioeconomic activities in that zone, and the amount of pollutants carried by treated water, especially heavy metals, as shown in the following equation:

$$TB_{5p}(t) = CH_{5p}(t) + TB_{2p}(t) + CI_{5p}(t) \quad \ldots\ldots(6)$$

**2-3-2. Water balance and water quality**

***Barada River***:

The following equations calculate the water balance at border of zones carried by Barada River as a basis for calculation the concentration of pollutants at those borders. That concentration is very important variable since the aim of proposed policy will be to decrease the pollutants concentration to meet the standards:

$$F_1^B(t) = Q^B + R_1 + W_1(t) + G_1 - E_1 - DW - Ir_1 \quad \ldots\ldots(7)$$

$F_2^B(t) = F_1^B(t) + R_2 + G_2 + W_2(t) + W_3(t) - E_2 - TW(t) - Ir_2$ ……………………….……...…….(8)

$F_5^B(t) = F_2^B(t) + R_5 + G_5 + W_5(t) - E_2 + TW(t) - Ir_5$ …………………………………………...…(9)

$W_2(t) = TW(t)$ …………………………………………………………..…………….…………(10)

$F_1^B(t), F_2^B(t), F_5^B(t)$: Flow of The Barada River at the border between zones 1&2, 2&5, and 5&6 respectively.

$TW(t)$: Amount of treated water in the Adra treatment plant.

$W_1(t), W_2(t), W_3(t), W_5(t)$ : Amount of wastewater flow to Barada River in zones 1,2,3,5 respectively.

The following variables are exogenous because according to data available, they can not be expressed dynamically:

$Q^B$ : Amount of spring water flows to Barada River.

$R_1, R_2, R_5$: Annual average rainfall in zones 1, 2, 5 respectively.

$G_1, G_2, G_5$: Annual ground water pumped from wells in zone 1, 2, 5 respectively.

$Ir_1, Ir_2, Ir_5$: Annual water used for irrigation in zones 1, 2, 5 respectively.

$E_1, E_2, E_5$: Annual average evaporation in zones 1, 2,5 respectively.

$DW$ : Annual average amount of drinking water pumped from the Figeh Spring to Damascus City .

The following equations calculate the water quality for each pollutant discharged to Barada River at the border between zones based on simple dilution model [1]. The concentrations of the pollutants at these points affect the evaluation of the water quality:

$Wq_{1p}^B(t) = (1-\zeta_1)TB_{1p}(t) / F_1^B(t)$ …………………………………………………….…(11)

$Wq_{2p}^B(t) = (1-\zeta_2)\{(1-\zeta_1)TB_{1p}(t) + TB_{3p}(t)\} / F_2^B(t)$ ……………………..………………..…(12)

$$Wq_{5p}^B(t) = (1-\zeta_5)\left\{\begin{matrix}(1-\zeta_2)\begin{bmatrix}(1-\zeta_1)TB_{1p}(t) \\ +TB_{3p}(t)\end{bmatrix} \\ +TB_{5p}(t)\end{matrix}\right\} / F_5^B(t) \quad \text{……………………………………..…(13)}$$

$Wq_{1p}^B(t), Wq_{2p}^B(t), Wq_{5p}^B(t)$ Quality of water at the border between zones 1&2, 2&4, 4&5, and 5&6 respectively.

$\zeta_1, \zeta_2, \zeta_5$: Natural purification coefficients for the zones 1,2,5 respectively.

The concentration of pollutants after treatment is very essential to examine since this water used for irrigation. The following equation calculates the pollutant concentrations after released from the treatment plant.

$Wq_p^T(t) = \lambda_p TB_{2p}(t) / W_2(t)$ ………………………………………………………(14)

***Awaj River***:

$F_7^A(t) = Ir_7 + G_7 + Q^A + R_7 + W_7(t) - E_7$ ……………………………………………......….(15)

$F_9^B(t) = Ir_9 + F_7^A(t) + R_9 + G_9 + W_9(t) + W_8(t) - E_9$ …………………………………………(16)

$F_7^A(t), F_9^A(t)$: Flow of The Barada River at the border between zones 7&9 and 9&10 respectively.

$Q^A$ : Amount of spring water flows to Awaj River.

$R_7, R_9$: Annual average rainfall in zones 7,9 respectively.

$G_7, G_9$: Annual ground water pumped from wells in zone 7,9 respectively.

$Ir_7, Ir_9$: Annual water used for irrigation in zones 7,9 respectively.

$E_7, E_9$: Annual average evaporation in zones 7,9 respectively.

$W_7(t), W_8(t), W_9(t)$: Amount of wastewater flow to Barada River in zones 7,8,9 respectively.

$$Wq^A_{7p}(t) = (1-\zeta_7)TB_{7p}(t) / F^A_7(t) \qquad (17)$$

$$Wq^A_{9p}(t) = (1-\zeta_9)\begin{Bmatrix}(1-\zeta_7)TB_{7p}(t) \\ + TB_{9p}(t)\end{Bmatrix} / F^A_9(t) \qquad (18)$$

$Wq^A_{7p}(t), Wq^A_{9p}(t)$ Quality of water at the border between zones 7&9, and 9&10 respectively.

$\zeta_7, \zeta_8, \zeta_9$: Natural purification coefficients for the zones 7,8,9 respectively.

The amount of wastewater

$$W_i(t) = \omega_i^p P_i(t) + \sum_j \omega_j Y_{ij}(t) \qquad (19)$$

**2-3-3. The economic model**

Since the economic data is very limited the economic model is simple one.
We assume that the relation between population and number of workers in each zone is constant by the time since we examined the correlation between number of workers and percentage of working population from year 1990 to 2000and it was almost constant:

$$\sum_j N_{ij}(t) = \tau_i P_i(t) \qquad (20)$$

$\tau_i$: The percentage of working population in zone i.

$\delta_i$ : Demand for new working population due to new investment.

$$P_i(t+1) = (1+\eta_i)P_i(t) \qquad (21)$$

The following assumption based on Harrod-Doman production function [23]. An increase of production requests an increase of labor:

$$N_{ij}(t) \geq \beta_j Y_{ij}(t) \qquad (22)$$

$\beta_j$ Labor force required per production unit in industry j.

Also the demand of the capital:

$$K_{ij}(t) \geq \alpha_j Y_{ij}(t) \qquad (23)$$

$\alpha_j$ : The capital required per production unit in industry j

$K_{ij}(t)$: Capital stock of industry j in zone i at time t.

Capital is accumulated by investment in each industry, in each zone at each time period:

$$K_{ij}(t+1) = (1-\sigma_j)K_{ij}(t) + I_{ij}(t) \qquad (24)$$

$\sigma_j$ : The depreciation rate.

$I_{ij}(t)$: Investment in zone i, industry j at time t.

The gross regional product (GRP) for any zone is the sum of total production (all industries) multiplied by the value added of production in each industry:

$$GRP_i(t) = \sum_j \mu_{ij} Y_{ij}(t) \quad \text{.....................................................................(25)}$$

$GRP_i(t)$: Gross regional product of zone i at time t.

$\mu_{ij}$ : The value added ratio in industry j and zone i.

On the other hand, the gross regional product equal to consumption plus investments and net transfers (subsidies to or borrowing from) to other zones:

$$GRP_i(t) = C_i(t) + \sum_j I_{ij}(t) + NE_i(t) \quad \text{..........................................................(26)}$$

The consumption is the population of every zone times the consumption per capita:

$$C_i(t) = \varepsilon_i P_i(t) \quad \text{...............................................................................................(27)}$$

$\varepsilon_i$ : Consumption per capita.

$C_i(t)$: The consumption in zone i at time t.

The objective function

$$MAX = \sum_t \left( \frac{1}{1+\rho} \right)^t GRP_i(t)$$

s.t equation (1)

## 3. Simulation results

We run simulation for 10terms of time from year 2000 using software called LINGO.

### 3-1. Total pollution to rivers

Results show that amount of chromium, cadmium, and lead is increasing steadily along the years. That corresponds with the stable economic growth of the basin (Table 7).

Table 7: Amount of heavy metals in rivers along simulation years

| Time | Barada River | | | Awaj River | | |
|---|---|---|---|---|---|---|
| | Cr(t/y) | Cd(kg/y) | Pb(kg/y) | Cr(t/y) | Cd(kg/y) | Pb(kg/y) |
| 2000 | 295.2945 | 563.8889 | 657.9635 | 1.529128 | 145.1403 | 109.8453 |
| 2001 | 310.0592 | 592.0833 | 690.8616 | 1.605584 | 152.3973 | 115.3376 |
| 2002 | 325.5622 | 621.6874 | 725.4047 | 1.685863 | 160.0172 | 121.1045 |
| 2003 | 341.8403 | 652.7718 | 761.6749 | 1.770157 | 168.0181 | 127.1597 |
| 2004 | 358.9323 | 685.4104 | 799.7587 | 1.858664 | 176.419 | 133.5177 |
| 2005 | 376.8789 | 719.6809 | 839.7466 | 1.951598 | 185.2399 | 140.1936 |
| 2006 | 395.7229 | 755.665 | 881.7339 | 2.049178 | 194.5019 | 147.2032 |
| 2007 | 415.509 | 793.4482 | 925.8206 | 2.151636 | 204.227 | 154.5634 |
| 2008 | 436.2845 | 833.1206 | 972.1117 | 2.259218 | 214.4384 | 162.2916 |
| 2009 | 458.0987 | 874.7767 | 1020.717 | 2.372179 | 225.1603 | 170.4061 |

It is conducted that chromium is discharged in highest amount comparing to cadmium and lead. Besides, is higher in Barada River because most of the tanneries, which generate huge amount of chromium is concentrated along Barada River (Figure 1)

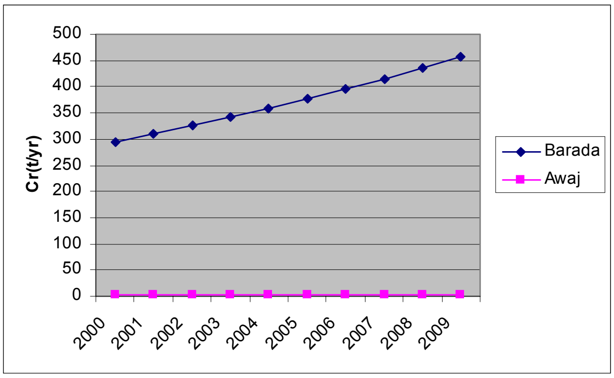


Figure 1: Amount of chromium flow to rivers

For the case of cadmium and lead is discharged to Barada River in higher quantities than in Awaj River (Figure 2&3)

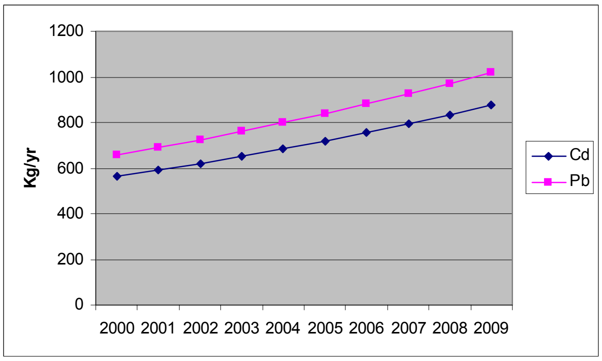


Figure 2: Amount of cadmium and lead flow to Barada River

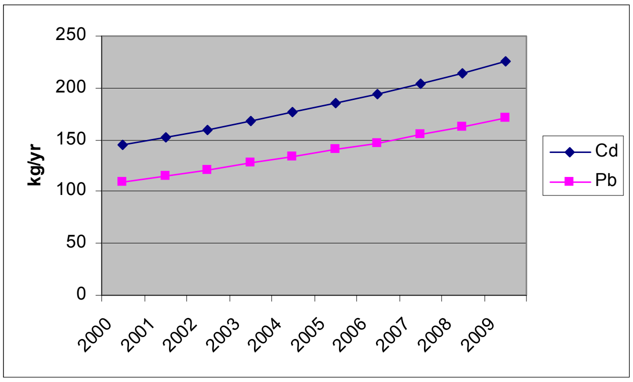


Figure 3: Amount of cadmium and lead flow to Awaj River

**3-2. Water quality**

Water quality results are very important to demonstrate the change of metal concentration along rivers, particularly in the border points between zones thus it show the participation of each zone in the contamination of the river.

**3-2-1 Barada River**: Dissimilar to down stream, upstream is not polluted since the industrial activities in zone 1 and 3 are few and limited to food industry and scattered firms for assembling devices. However, in zone 4 the leather, smelting, battery production, and other cause to increase of amount of heavy metals but still not exceed the standard (Figure 4).

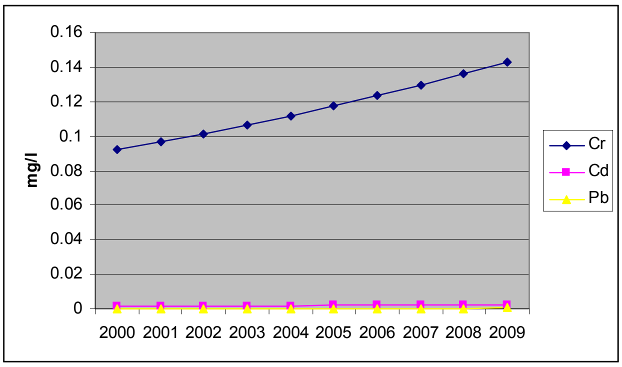


Figure 4: Concentration of pollutants in the border between zones 4&5

For zone 5 with decrease of water flow beside its own manufacturing and pollution received from zone 2 the concentration increase around ten times more than allowable limits as shown in Figure 5 and 6.

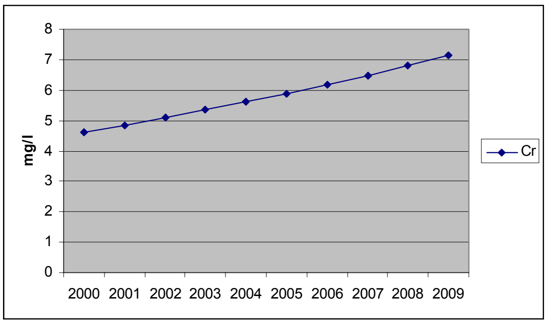


Figure 5: Concentration of chromium in the border between zones 5&6

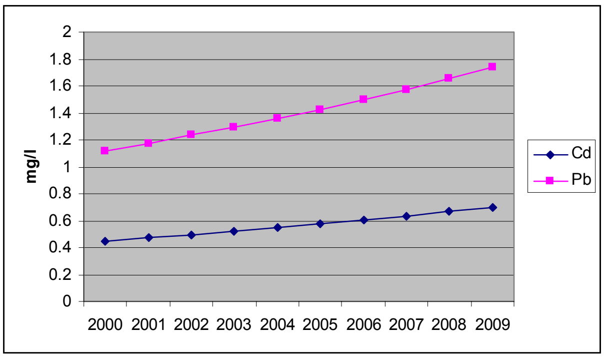


Figure 6: Concentration of cadmium and lead in the border between zones 4&5

**3-2-2 After Adra treatment plant**: since this plant does not contain any treatment for heavy metals, again these pollutants discharged in extremely high concentrations (Figure 7&8). Unfortunately, the treated water is used for irrigating green vegetables and crops, which carry obviously tremendous danger for inhabitants and directly to human health in the whole study area since zone 5 the main supply for vegetables for other zones. For this reason risk assessment for these chemical on human health must be undertaken [1][24]

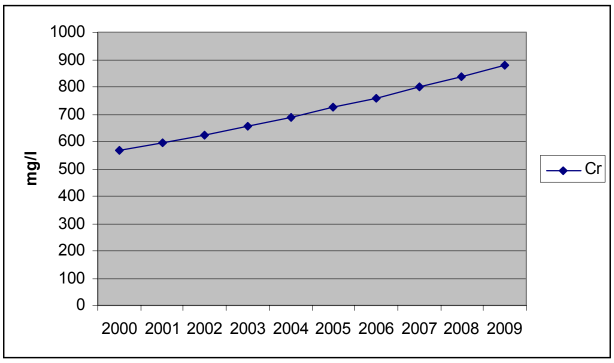


Figure 7: Concentration of chromium after discharged from treatment plant

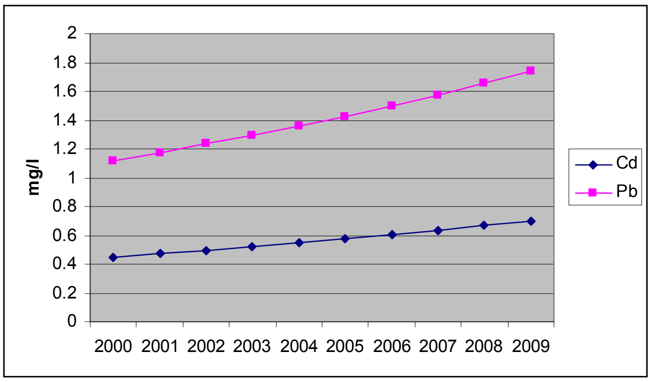


Figure 8: Concentration of cadmium and lead in the border between zones 4&5

**3-2-3 Awaj River**: The situation in Awaj River not serious comparing to Barada River since the industrial activities not heavily concentrated along this river. Upstream the concentration is almost zero and downstream (zone 9& 10) the concentration less than the standard. However, according to MLA few samples did show concentration in the downstream more than standard [14]. This is significant indicator that chemical accumulation is taken place in the surface water and the results we demonstrate here is just display how much heavy metals generate annually though the real condition may show higher number.

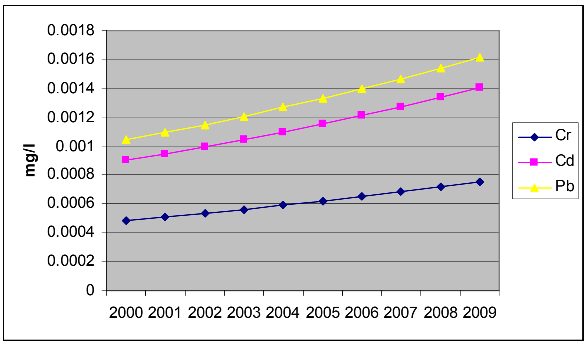


Figure 9: Concentration of pollutants in the border between zones 9&10

### 3-3. Manufacturing contribution

Since the demand of investment is equal (according to model specification) among the manufacturing industries, the contribution of generating pollutants is constant along simulation years. However, this contribution varies among zones since the industrial activities are different in these zones. This dissimilarity is reflected in the model with two variables: production and investment and one parameter: emission coefficients from industrial activities. In case of production and investment data for initial year is available but for the emission coefficients we had to estimate those using specific data and guidelines. These coefficients widely differ in the zones due to variety of manufacturing types. For instant, under textile industry there are many sub-sectors such as, dying, leather, or just cotton processing. Leather processing generate huge amount of chromium and lead while cotton dealing produce just BOD. Getting directly to the point, the range of pollutant quantity among zones is very important to be determined in order to introduce specific policy measures for each zone. Ignoring that leads to equal sharing of responsibilities, this means unfair sharing of mitigation cost among in these zones.

Getting back to the results, in case of chromium, textile industry is the main contributor in zones 2,4,5, and 8 while chemical industry take all part in zone 3 and 10 and 55% of zone 6. In zone 9 and 45% of pollution in zone 6, the contribution is from metal industry as shown in Figure 10.

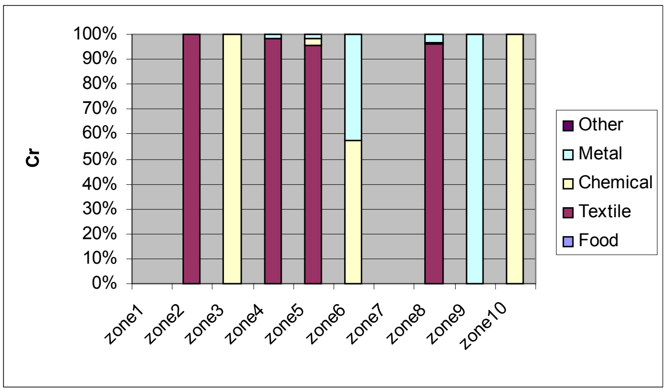


Figure 10: Contribution of manufacturing industries in generating chromium

Figure 11 shows that main source of lead in zone 2 and 8 from textile while 50% in zone 4 and less than 40% in zone 5. Moreover, chemical industry in the only source of lead in zone 3 and 10 and 70% in zone 6, while metal is the only contributor in zone 9.

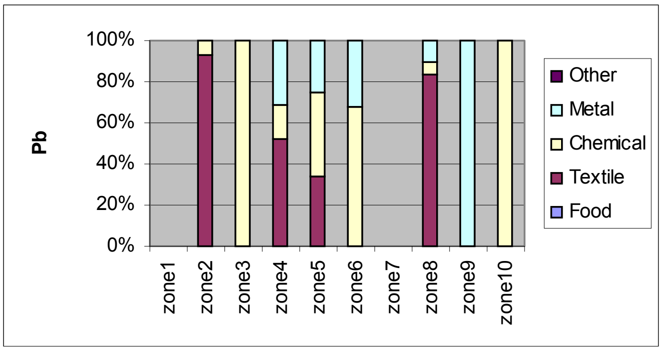


Figure 11: Contribution of manufacturing industries in generating lead

In case of cadmium chemical is the main contributor in zone 3 and 10, while metal industry has the same role in zone 4, 6, and 9 and 55% in zone 8. For textile industry, it is the main source in zone 2 and less than 50% in zone 8 (Figure 12)

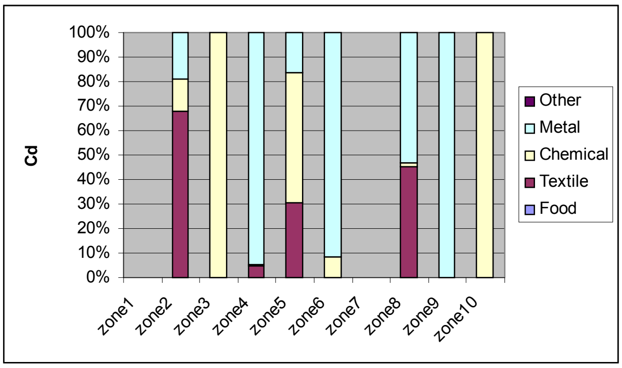


Figure 12: Contribution of manufacturing industries in generating cadmium

## 4. Conclusion

In this paper we analyze the problem of heavy metals generated from manufacturing industries as point-source of pollution by running simulation for mathematical model to determine the amount of chromium, cadmium and lead discharged and clarify the contribution of these pollutants by sectors and zones. The results show that the amount of pollutants varies among sectors and zones. However, Barada River is highly polluted especially in downstream and zone 2 contributes the most of such contamination. Moreover, the chromium is the most serious element since it concentrates in excessive quantity, particularly in zone 5 where the water in this area used for irrigating vegetable and crops, which may high risk to human health.

Consequently risk assessment of these pollutants on human health is definitely required to investigate the degree that inhabitants in the study area are in danger, number of people under defined levels and types of risk are exposed, and predict mortality cases due to cancer. This should be carried out considering the data available in order to reduce uncertainty in assumption as much as possible because depending on the assessment results it would be decided the necessity of risk management.

As a conclusion, the model can be considered conceptual since the results we obtain correspond as an overview with previous studies and present samples. Precisely, it did provided a detailed quantitative records and more specific qualitative information can be a basis for further studies.

The simulation results are essential basis for further steps because:

1. Estimating the amount of specially serious heavy metals, Cr, Cd, Pb, will enable us to introduce specific abatement facilities for each type of manufacturing sectors to remediate the contamination.
2. Predicting the effect of economic growth on increasing the load of pollution in long-term, allow us to introduce and analyze an optimal policy to reduce the water pollution in the basin.
3. Studying the contribution of pollution loads among zones would determine the adequate sharing of mitigation cost and introduce various economic instruments regarding each district.
4. Determine the necessity of risk assessment of heavy metals on environment and human health in particular.

## References


[1] C.J. Van Leeuwen and J.L.M. Hermens (1995): Risk Assessment of Chemicals: An Introduction, Kluwer Academic Publishers, Dordrecht, The Netherlands, 374p.

[2] Edward Kuiper (1971): Water Resources project economics, Butterworth & Co Ltd., London,447p.

[3] Falouh J. (2000): Water Resources in Barada and Awaj Basins, Ministry of Irrigation documents, Damascus (Arabic).

[4] Higano Yoshiro, Hirose F. (2000): A Simulation Analysis to Reduce Contamination from the Catchment Area of Lake Kasumigaura, Studies on regional science Vol.30, No. 1, pp. 47-63.

[5] Higano Yoshiro, Takayuki Sawada (1995): The Dynamic Optimal Policy to Improve the Water Quality in Kasumigaura Lake, Studies on regional science Vol.26, No. 1, pp. 75-86.

[6] Ikkatai, Seiji (1998): The latest State of The Water Quality Management Policy, Journal of Resources and Environment, Vol.34, No. 3, pp 5-10.

[7] James A. (1978): Mathematical Models in Water Pollution Control, Chichester, Wiley, 420p.

[8] JICA (1996): Developing Water Supply System for Damascus City: Phase I, Ministry of Environment documents.

[9] Ministry of Environment (1996): Syrian Standard for Wastewater Discharged to Sewerage System,, Ministry of Environment Document, Damascus (Arabic).

[10] Ministry of Environment (1995): Heavy Metal Analysis for Vegetable, Ministry of Environment Document, Damascus (Arabic).

[11] Ministry of Environment (2001): National Overview of Chemicals Pollution and Safety, Ministry of Environment Document, Damascus (Arabic).
[12] Ministry of Housing (2000): Adra Treatment Plant, the Ministry of Housing documents, Damascus.
[13] Ministry of Industry and Mineral Resources (2000): Statistics of the Economic Activities, Documents of Ministry of industry, Damascus (Arabic).
[14] MLA ( 1996): samples results from the labs of municipalities, Ministry of local administration(Arabic).
[15] Ministry of Supply(2000): Specific Economic Data, Documents of Ministry of Supply, Damascus (Arabic).
[16] Shawaf S. (2000): The Contamination of Barada River, Ministry of Irrigation documents, Damascus (Arabic).
[17] Statistic institute(2000): Statistic Handbook for Syria, Damascus.
[18] WHO(1993): Assessment Of Sources Of Air, Water, And Land Pollution, Environmental Technology Series, Geneva
[19] William J. Baumol, Wallace E. Oates (1979): Economics, Environmental Policy, and The Quality of Life, Prentice-Hall, Inc., Englewood Cliffs, USA.
[20] World Bank (WB), United Nation Environmental Program (UNEP), and Ministry of Environment (1997): PEAP for *Barada Basin*, Ministry of Environment documents, Damascus.
[21] WB(1994): The Industrial Pollution Projection System IPPS, World Bank.
[22] World Bank Group(1998): Pollution Prevention and Abatement Handbook, World Bank.
[23] Valery L. Makarov, Mark J. Levin, Alexander M. Rubinov(1995): Mathematical economic theory, : Elsevier, North-Holland, Amsterdam, 610p.
[24] Vincent T. Covello, Miley W. Merkhofer (1993): Risk assessment methods : approaches for assessing health and environmental risks, Plenum Press, New York, 267p.