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Ecological Impact Analysis on Mahshahr Petrochemical Industries Using Analytic Hierarchy Process Method

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ABSTRACT: Petrochemical Industries are potentially capable of impacts on environment due to the essence of the activities and producing waste water, pollutant emissions and hazardous wastes. This case study has considered the environmental adverse impacts of petrochemical industries on existing habitats in Mahshahr Economic Special Zone with respect to the regional significant biological diversity and ecological valuable species. When results from regional estuary sampling as well as impacts by petrochemical industries pollutants has been analyzed and studied. Then affected ecosystems have been prioritized using Analytic Hierarchy Process (AHP) method, Expert Choice software and Eigenvector technique. Studies outcomes show that, with regard to petrochemical industries pollutants, especially waste waters including heavy metals, oil and grease, Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), along with criteria defined in AHP method such as ecological and protecting value, estuaries are most affected ecosystems in the region. On the other hand, types of fishes and benthic, such as Decapods, Gastropods and Tanaida have been highly affected by the petrochemical industries activities consequents. It is concluded that, heavy metals, oil and grease, deposit into the environment, are the most important pollutant sources for the regional estuaries which should be controlled

Key words: Petrochemical Industries, Impacts, Analytic Hierarchy Process, Expert Choice, Estuaries, Environment

INTRODUCTION

Petrochemical Industry refers to those industries in which Hydro Carbon within the natural gas and oil is transformed into chemical products. “Petrochemical”, which implies chemical materials obtained from oil, is compound of two words indeed; “petrol” and “chemistry” (Monavari, 2001). Petrochemical industry is the industry that produce our daily life needed chemical materials from oil by processing and transforming Hydro Carbon into final products which have about 10 to 15 times higher value added than its feed stock namely gas and crud oil. Other advantages of this base industry is it’s infinite possibility of producing thousands of chemical products that many of them are used as feed to other industries and agriculture. (Jafarzadeh, 2008).

Petrochemical Industry has been established first in America. The word “Petrochemicals” was used to refer to raw materials achieved from oil. Then after oil material was used as primarily raw materials by European and other countries. National Petrochemical Company (NPC) subsidiary of National Iranian Oil Company (NIOC) has been established in Iran since 1964 and began its activities about half a century ago (Mostajabi, 2008).The first relatively cohesive organization which has been established for the purpose of petrochemical activities was chemical institute affiliated to ministry of economy and its major work was foundation of chemical fertilizer factory in Marvdasht-Fars in 1957. Later in 1964, all the activities entitled Petrochemical Industries Development by ministries affiliates and other governmental organizations, have been centralized in National Iranian Oil Company (NIOC) and subsequently established National Petrochemical Company as a subsidiary in order to fulfill the main objective which is producing chemical, petrochemical and side products from oil and gas derivations and other organic and mineral materials. Thus, Hydro Carbon which are frequently found in Iran and

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has been previously burnt as solid useless waste for many years, now are being used according to scientific and industrial standards (Rafeenejad, 2007).

Although petrochemical industries brought too many benefits for our life, are considered as environmental pollutant source it could be said that control and mitigation of petrochemical industries pollution have been a cause for concern and today's international major challenges to save the environment against its impacts. The environmental impact of these industries, if the environmental standards and regulations are ignored, could cause hazardous impacts and make great disturbance to the health of human community as well as wildlife (Rooney, 2005). Petrochemical industries potentially have environmental impacts due to the essence of their activities and process, as well as its producing waste water, emissions and hazardous wastes (Xiao-ping, *et al.*, 2004). Moreover, industrial waste water deposit to the environment by petrochemical industries, regarding the nature of the waste composition, is capable of destroying significant amount of biological elements of the water resources that receive these wastes and gradually eliminates aquatic types of fauna and flora directly or indirectly which follows by food network simplification as the number of species and diversity decrease and finally change the water resource to a dead one (Rajesh and Edwin Tam, 2006). These impacts not only affect the biological factors of the ecosystem especially in case of heavy metals pollution, but also can affect the water resource quality and threat the human health as well (Esmaeli Sari, 2002). According to sustainable development and environmental standards, ignoring environment and threatening environmental and biological factors is equal to ignoring human health which follows by health, social and economical impacts (Asian development bank, 1997).

With respect to this subject, discharging waste by several petrochemical industries into the Persian Gulf affects regional natural life of animals in the sea which are considered as nutrition source to the residence of the area and consequently threatens human health. Persian Gulf is a semi open sea with 40000 m^2 areas and between 400 and 450 types of fishes which is very unique diversity indeed. Persian Gulf is located in a dry and warm climate. With respect to special environmental condition, regional aquatic species are rather vulnerable against climate changes in one hand and regional pollutants have doubled the harm on the other hand (Samadyar, 2005).

Studied area is located on Persian Gulf shore in Mahshahr County which has a strategic position amongst Iranian oil & gas area due to petrochemical industries plant operating there and makes the feed stock oil and gas resources available to the plants (Jafarzadeh, 2008). Estuaries are the most important regional aquatic ecosystems. Appropriate temperature and food condition in these ecosystems make the situation suitable for abundant types of fishes, benthic such as Tanaida, Polychaeta, molluscs. In addition, types of indigenous and peregrine birds, living in the study area, which are mostly regional native birds or migrated to this place each year from cold regions to hibernate, prove the importance of estuary's ecology near the study area (Nabavi, 1999). Great amount of discharged waste water into these estuaries is the major water pollution factor. On the other hand frequent tide has considerably expanded the scope of pollution. Pollution in Mousa estuary and its tributary originates from the estuary (Mazaheri 2001). Therefore, regarding estuaries as one of the most productive ecosystems on the world in one hand and several petrochemical industries activities in the region on the other hand, degradation factors exploration and defining the characteristic pollutants in the region to provide appropriate mitigation measures in order to remove or decline the adverse impacts, become inevitable necessity.

In this study, adverse impact caused by petrochemical industries activities located in Mahshahr economic special zone of, focusing on Tondguyan Petrochemical Complex has been analyzed. This complex is considered as the only PET (Poly Ethylene Terephthalate) bottle manufacturer in Iran, which possesses a waste treatment system independently. The main reason of constructing this treatment plant and not just send the waste to Fajr plant, what other petrochemical industries just do, is the existence of heavy metal in the complex waste (Mg and Co for instance), high COD and a large quantity of the produced waste by Tondguyan Complex. (Shil Amayesh Consulting Engineers, 2006).

Now a days, environmental impact assessment and analysis of petrochemical industries waste waters on biological communities particularly those factors which are more vulnerable against pollutions, is one of the main measurements which is taken in to account to protect natural resources. Assessment and analysis of impacts must be done along with carrying out required sampling from affected water resources in a way that guarantees the protection of affected biological factors. Therefore environmental management with the purpose of protecting these affected resources requires impacts identification and analyzing (Jafarian, 2008). Although obeying environmental requirements deals with mitigation or declining of the most significant incompatible environmental impacts involves costs, it offers a more promising future in terms of environmental issues, and specially will bring the opportunity to join the Kyoto Protocol for countries (Mostajabi, 2008).

In this study, Analytic Hierarchy Process (AHP) method has been used to rank the pollutants and environmental impact assessment of petrochemical industry. Since Analytic Hierarchy Process theory came to exist, many essays have been published focusing on that and some magazines have specialized particular published number to those essays. European Journal of Operational research journal as specialized one, Socio- Economic planning magazine and Mathematical Modeling journal has specialized two volumes separately to discuss the AHP and multiple criteria decision making (Saaty, 1994). In addition about 20 volumes of books have been published and different conferences have been hold all around the world in related to AHP method (Ghodsipur2006). Application of AHP method in environmental projects and plans is being frequently discussed in many essays. This method has also been used in environmental impact assessment of this case study, petrochemical industries, and pollutants ranking. Objective and subjective evaluation of power plants and their non-radioactive emissions, an essay by Athanasios, has evaluated incompatible environmental impacts of 10 power plants using analytic hierarchy process method and it concluded that nuclear, water, geothermal and wind power plants have less environmental impacts (Athanasios, *et al.,* 2007).Moreover, Ramanathan, R used this method in assessing socio-economical impacts of the construction of a recycling factory in India. The assessment was done based on public participation from nearby city and countryside in a plebiscite. Results showed that water supply is a major problem among the people from both city and countryside (Ramanathan, 2001).Another example of AHP application is an essay published by Solnes, J., in which, the environmental quality of the development of the three industries, namely, aluminum factory, oil refinery and regional industries has been determined and the result showed that, the least environmental impacts go to regional industries development (Solnes, 2003).

MATERIALS & METHODS

Regional major habitat and biological characteristic have been studied and identified. At first, the most important regional affected habitats by petrochemical activities have been identified by means of hierarchy tree formation and outlined criteria and sub-criteria. Then, subsequent pollution of different process units at the state petrochemical complex as well as other petrochemical industries along with areas of environmental potential pollution have been studied at second step.

Water pollution and aquatic species diversity in confined and unconfined parts of estuaries has been observed through biological and physio-chemical factors test results analyses , which have been sampled from different stations on nearby estuaries. Along with it, effluent treatment discharge of petrochemical complex has been measured in three periods of time, each three months alternatively, and their average has been compared to those standards of department of environment.

Finally, according to test results and the amount of influence on the effect receiver environment towards identified pollutant factors, five major types of water pollutants have been recognized, chosen and ranked, which include heavy metals, oil and grease, COD, TSS and H_2S . Then, AHP methods with Expert Choice software were used to rank the water major environmental pollutants and to study their impacts. In this method, relative weight of defined criteria and sub-criteria in relation to each other and their immediate upper layers have been measured using Eigenvector technique, thereof, alternative's final weight has been calculated and studied, and pollutants ranked based on assigned criteria. Having recognized the most important environmental pollutants, mitigation measures have been provided and advised consequently. Fig.1. shows the stages of this study.

With the purpose of identifying the most important affected ecosystem by petrochemical industries, the first step has been specialized to the formation of hierarchy tree. In this formation, the second level of hierarchy tree belongs to ecological value, protecting value and exposure of the regional state environment within the study area as well as their vulnerability towards petrochemical pollution such as water, air, noise pollution and solid waste as main criteria. Habitats affected by petrochemical industries within the study area are considered as alternatives which are given on the last level (Fig. 2).

As seen on step two, hierarchy tree has formed with the purpose of ranking the environmental impacts on the most important ecosystem, which has been identified on step one. In this structure, environmental degradation major criterion has been evaluated. Ecological value, vulnerability and pollutants density are considered as three major criteria to determine the environmental impacts, and aquatic habitats as sub-criteria of this hierarchy tree, which has been classified into four parts including Zangi estuary confined and unconfined area, Mousa and Jafari estuaries. These four parts have been through a pair wise comparison with each other relation to major criteria. The impacts on all types of living parameters such as density and diversity of aquatic vegetation, fishes, and peregrine

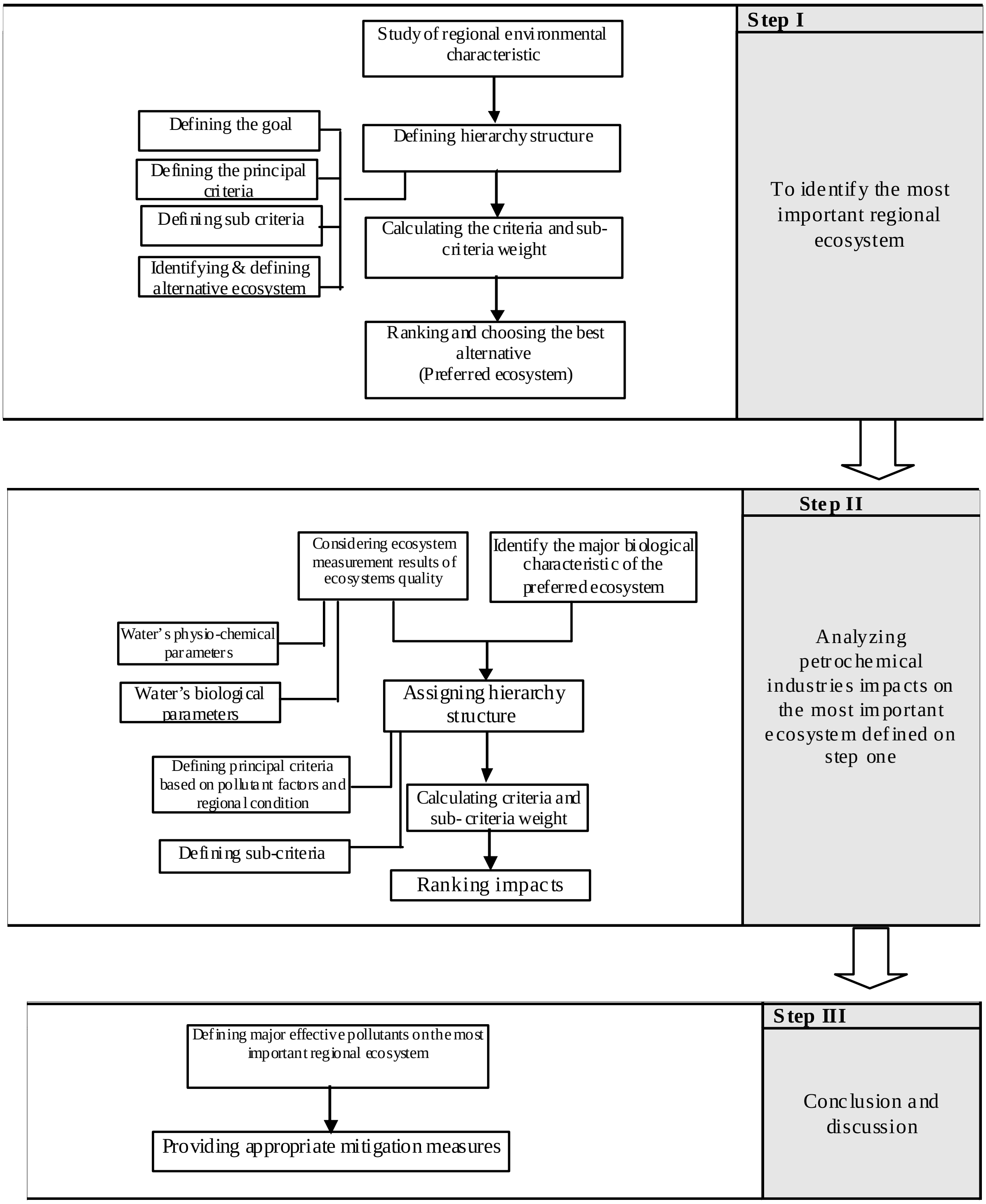

Fig. 1. Study stages

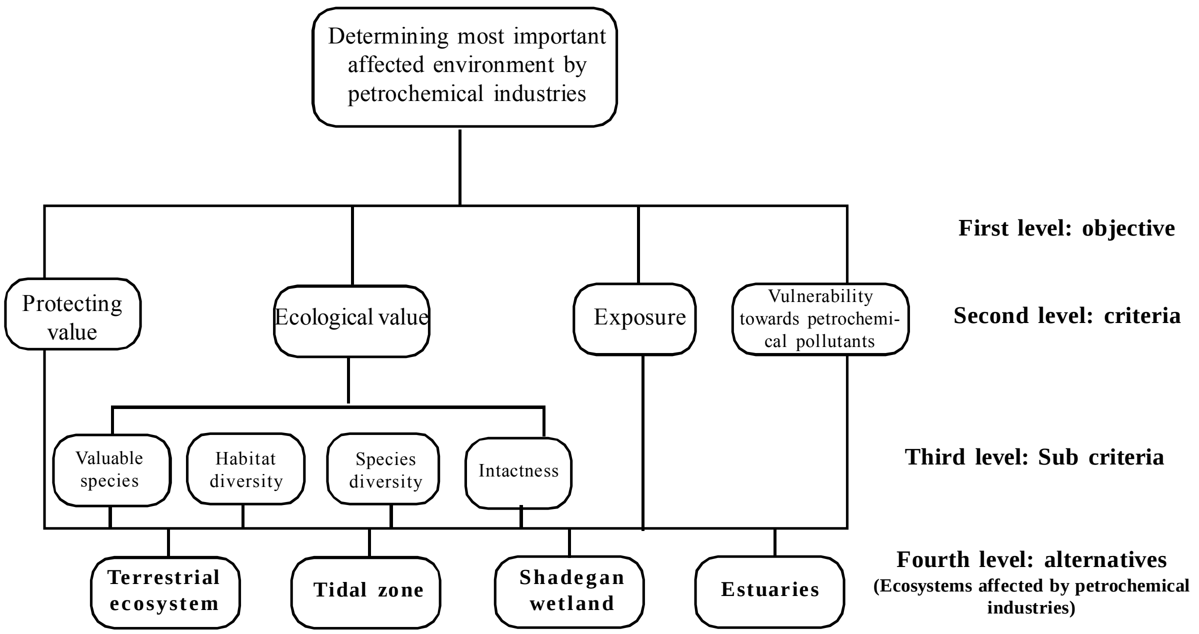

Fig. 2. Hierarchy tree to identify most important affected ecosystem

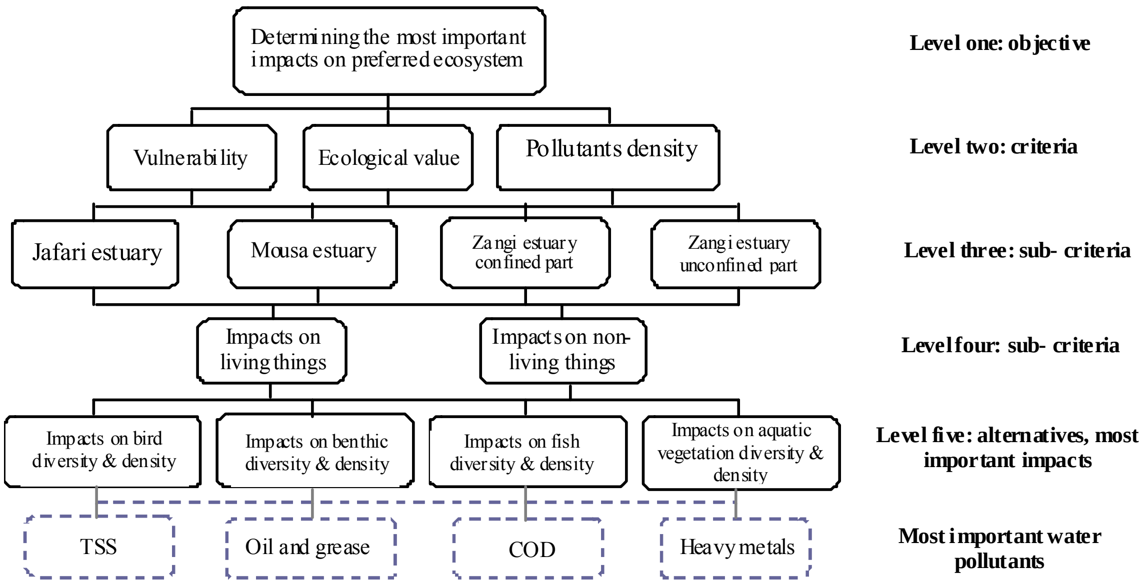

Fig. 3. Hierarchy tree to identify most important impacts on preferred ecosystem

birds, benthic and aquatic bird's likewise non-living parameters (physio- chemical) such as salinity, suspended solid matters, temperature, and pH have been weighted and measured (Fig. 3). In order to evaluate the alternatives, different criteria should be ranked by considering weight for each criterion and sub- criterion, in this research to be able to distinguish more important alternatives (environmental pollutants). These relative weights were only considered for the purpose of ranking criterions using pair wise comparison method. In this method more important criterion is being assigned between each couple and qualitative phrases. Pair wise comparison converts qualitative comparison into quantitative weight for all factors (Asgharpur, 2006) (Table 1).Preference Matrix for each level in relation to its upper level has been prepared in this method. The first row and column contain parameters of each level, then every parameter of each level

Table 1. Preference qualitative for pair wise comparison method (Ghodsipur, 2006)

Value	Preferences
9	(Extremely Preferred)
7	(Very strongly Preferred)
5	(Strongly Preferred)
3	(Moderately Preferred)
1	(Equally Preferred)
8 .6 .4 .2	-

being compared to parameters of upper level through pair wise comparison. If criteria in a row (i) are more important than those of column (j), this importance will be shown by integral number. On the other hand, if criteria of column (j) are more important than those of row (i) then this importance will be shown with fractional number (Villa and Mcleod, 2006) (Table 2).

Table 2. Preference matrix and pair wise comparison of criteria in each level in relation to upper level

	j_1	j_2	j_n
i_1	1		
i_2		1	
i_n			1

In this method criteria weight (w_i) are assigned in a way to make hereunder relations accurate:

$$a_{11} w_1 + a_{12} w_2 + \ldots + a_{1n} w_n = \lambda.w_1$$

$$a_{21} w_1 + a_{22} w_2 + \ldots + a_{2n} w_n = \lambda.w_2$$

$$a_{n1} w_1 + a_{n2} w_2 + \ldots + a_{nn} w_n = \lambda.w_n$$

If an equation, in which, a_{ij} is criterion i preference to criterion j, and w_i is criterion i weight and λ is invariable figure. Then w_i is calculated as below:

$i = 1, 2, \ldots, n$ $\quad\quad$ $W_i = 1/\lambda^n$ “$a_{ij} w_j$

$A. W = \lambda. W$

This equation which is the same as pair wise comparison matrix, it means, $\{A = [a_{ij}]\}$. W is weight vector and λ is a scalar figure (Roberts, *et al.*, 2001; Ong, *et al.*, 2001).

Determinant matrix (A- λ.I) is calculated for each A matrix and been equaled to 0, thereof λ quantities resulted. The biggest λ applied to (A-λ max I) =0 and finally, (W_i) has been computed for each criterion. The whole computing process done by Expert Choice software. Final weight of each alternative is equal to total product of criterion and alternative's weight (Ghodsipur, 2006).

Ecosystems prioritizing matrix in the study area identifies the biggest relative weight as the most important affected ecosystem by petrochemical industries activities and, petrochemical industries pollutant ranking matrix each alternative with the biggest weight is considered having the most incompatible environmental impacts and requires more efficient mitigation measures.

RESULTS & DISCUSSION

According to the studies, pair wise comparison on affected ecosystems in terms of ecological value and protecting value, tidal zones and Shadegan wetland, which both are protected and managed by department of environment, acquired top grade.

It should be mentioned that, in ecosystems pair wise comparison matrix based on exposure and vulnerability of the criteria towards petrochemical industries pollutants, estuaries and their tidal zones are located not far from those industries. Therefore, ran-offs in site of petrochemical complex, especially Tondguyan complex, and cooling towers blow down are discharged to the estuaries directly or through gathering channels in special zone. Moreover, waste waters of all petrochemical industries are being discharged to these aquatic ecosystems after being treated in the study area (Razavi, 2004). With respect to mentioned factors, these areas are more affected by petrochemical pollutants than other habitats in the study area and they have bigger weight in the related matrix Terrestrial ecosystems in the study area are restricted to plain habitats with a poor quality and have no significant fauna and flora diversity due to establishment of petrochemical industries in the region. Besides, the soil is salty and alkaline and it's not qualified to grow types of vegetation. Thus, this habitat enjoys no protecting value and considered as the last priority in terrestrial ecosystem's pair wise comparison matrix towards other affected ecosystems, in terms of all observed criteria in hierarchy tree, it gained the lowest relative weight.

In hierarchy tree, the most important environmental impact on preferred ecosystem, ecologic value and vulnerability with same relative weight has been ranked as first priority and the most important ones among three considered principal criteria on second level. The state petrochemical complex is equipped with separate treatment plant and measurement results show that, discharged materials from this waste treatment plants to estuaries exceed standard limits in terms of discharge to surface water (Table 3). Waste water produced by

Table 3. Average of effluent treatment factors which are more than standards limits in studied complex (Shil Amayesh Consulting Engineers, 2006; Jafarzadeh, 2008; DOE, 1999) – mg/L

Physio- chemical factors	Density (mg/L)					Standard limits of discharge to surface waters
	Speck No.2	Influent treatment Speck	Speck No.12	Speck No.13	Speck No.14	
BOD	120	275				30
COD	486.23	537.06		406.86	192.26	60
Oil & Grease	32					10
TSS	856	760	290			40
NH_4	3.3		4.4			2.5
Mg			132.48			100
pH		8.9	8.74	8.6	8.8	8.5-6.5
PO_4					8.46	6

BOD: Biochemical Oxygen Demand, **COD**: Chemical Oxygen Demand, **TSS**: Total Suspended Solids

other petrochemical complexes in Mahshahr is transferred to Fajr utility complex to be treated; therefore, the criterion for amount of pollution caused by pollutant factors from this complex and the other ones in the study area, has the least portion of environment degradation in the region and gain lowest weight on pair wise comparison matrix.

Results from estuaries comparison in terms of ecological value, vulnerability and amount of pollutant factors show that, Mousa estuary has highest ecological value and species density and diversity. Similarly, during investigation on Mousa estuary in 1999 overall 12 groups of micro-benthos have been identified and separated. Most frequently seen in percent are respectively 43.1% Amphipods, 41.6% Polychaeta, 3.5% Copepods and 3.1% Tanaida. They are most frequently seen on April about 17707 and the least on October 2407 n/m^2. 28 family of Polychaeta have been identified in this study (Nabavi 1999).

Natural water cycle and tide are partially disordered on Zangi and Jafari estuaries confined parts due to being separated from nearby water. Additionally, results from these estuaries's deposits and bed sampling indicate that, pollutants from petrochemical industries discharged into them has impoverished the aquatic species into poor and very few number of benthic types.Density and diversity of micro benthos in Zangi estuary confined parts are intensely affected by incoming pollutants, as biodiversity index is almost 1 and average of micro benthos density is 254 per m^2 which mainly includes larva and insects on the edge of estuary. Confined estuary bed has almost no living organism. Moreover results from researches state that biodiversity and density of micro benthos increase from confined towards unconfined areas in Zangi estuary (Manuchehri, 2008). Thus, in related matrix, confined parts of estuaries received lowest credit in terms of ecological value. Pair wise comparison based on vulnerability shows that Zangi estuary as the closest one to the petrochemical complex, subject to this study, is recognized as the most vulnerable one against petrochemical complex pollutants, while Mousa estuary's main tributaries is less vulnerable against petrochemical pollutants and is less exposed to petrochemical pollutants in comparison to other aquatic ecosystems.

Water quality measurements on confined and unconfined parts of Zangi and Jafari estuaries indicate that the latter one is the most polluted estuary in the study area; moreover, confined parts are more polluted than unconfined waters (Table 4). Results from water quality sampling carried by Manuchehri, 2008 on these estuaries showed that confined areas which are closer to the Tondguyan petrochemical complex has higher amount of COD and pH, therefore in estuaries pollution comparative matrix, the biggest weight goes to confined and unconfined parts of Jafari estuary and the lowest weight goes to Mousa estuary.

According to pair wise comparison matrix of aquatics density and biodiversity, major adverse impacts caused by water pollutants is on fishes and benthic and impacts on their density and diversity gained the first priority in this matrix. Impacts on aquatic bird and vegetation are considered as second priority. Final step involves in comparing density average of water pollutants with standards of department of environment

Table 4. Average of water quality parameter on Zangi and Jafari estuaries (Mahshahr Economic Special Zone, 2001)

Sample point	Temperature o^C	pH	EC Sμ	Turbidity NTU	Density g/cm^3	TDS mg/L	Cl^- mg/L	Overall alkaline mg/L	OH^- mg/L	COD mg/L	T.B.C mg/L
Confined Zangi estuary	21.8	9.25	160.8	47.8	1.2724	459.5	206036	1317.1	0.28	2802	20≤
Unconfined Zangi estuary	22.5	8.4	68.12	29.4	1.0259	55.04	27969	151.16	0.04	197	245
Confined Jafari estuary	26.9	8.8	151.7	15.8	1.2728	453	194866	1145.5	0.11	2546	30≤
Unconfined Jafari estuary	22.3	8.4	67.58	25.8	1.0348	56.20	27767	152	0.04	82	100

and physico-chemical factors, which exceed standard limits, have been selected to identify and rank the degradation factors that decrease the ecological quality in these estuaries. According to results from measurements on effluent treatment discharge in petrochemical complex subject to this study, indicator pollutants are TSS (3132.13 ppm), COD (282.55 ppm), oil & grease, heavy metals respectively with average of 0.48 and 8 ppm.

Waste water containing heavy metals and oil compositions material has significant impacts on estuary's ecosystem that change reproduction, growth, behavior, habitat and food resources and increase aquatic organism's sensitivity (fishes and benthic and peregrine birds) towards pathogenic factors. On the other hand, these spreading materials on the surface water prevent aquatic plant to receive light and consequently prevent continuant photosynthesis process (Dakhteh, 2004).

According to Matrix of water pollutant impacts on aquatics in the estuaries, two aforementioned pollutant factors have been rated as first and second priorities. High density of COD has indirect relation with decrease of dissolved oxygen which together decline life quality of aquatics. In related matrix impacts caused by High density of COD on aquatic fauna and flora assigned as third priority. Moreover, high density of TSS makes respiratory disorder for fishes, deforms the bed of benthic habitat, blocks light from aquatic plants and restricts gaseous exchange. Impacts of these pollutants on living factors are considered as last priority in these estuaries.

CONCLUSION

According to matrix and pair wise comparison rating system, criteria of each level have been weighted compared to those of upper level of this study. Then final ranking of alternatives towards the objective has been carried out. Results from ecosystems weight assessment in the study area, show that, estuaries, especially their tidal zones are most vulnerable ecosystems affected by petrochemical industries activities and the petrochemical complex, subject to this study. Moreover, impacts on density and diversity of different types of fishes and benthic societies have identified as first priority. According to study of water pollutant criteria, oil and grease, heavy metals are recognized as most important petrochemical pollutants in this case study and other petrochemical industries which have the highest potential to effect biological condition of the estuaries. In this study, COD and TSS are respectively placed in third and fourth priority in terms of environmental impacts.

Ranking results from water pollutant indicators originated from studied petrochemical activities, as well as other petrochemical industries is calculated by Expert Choice software. According to the expert choice analysis the most important pollutants can be grouped as oil & Grease (0.33) > heavy metals (0.30) > COD (0.22) > TSS (0.15).
As a result, following mitigation measures are recommended:
- To monitor and control periodically in short intervals
- Waste treatment plant abatement and improvement
- To return the outgoing waste to Fajr utility plant in case of waste treatment system malfunction

- To Predict pre-treatment system in petrochemical complexes which produce waste with high load of pollution
- Discharge no surface ran-offs, cooling towers blow down in to the estuaries and direct them into the waste treatment system.
- To vacuum ran-offs effluent polluted by oily and grease matters
- To prevent disconnecting Zangi and Jafari confined estuaries from nearby water

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