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Water Quality Trading Using Tradable Permit in Biodiversity of River and Assessment of Efficiency of Expense

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A-B-S-T-R-A-C-T

Background & Aims of the Study: Due to one-way flow of water in rivers Guilan, pollution trade theory and the system of Ratio-Trade (TRS) and Streeter - Phelps equation has been used. This system, with a view of the river self- purification and how the distribution and transport of pollutants, determined Ratio-Trade system (TRS) between the units and using this method offers optimal pattern of pollution trade between emissions units.

Materials & Methods: Generally implementation of pollution trading plan was performed using transmission coefficient in the study area in 5 stages: zonation of the study area, qualitative changes in the dissolved oxygen (DO) and biochemical oxygen demand (BOD_5) along the Langeroud river, defining the standard total output load for each region and the initial allocation between the emission sources, defining the transmission coefficients between the emission sources and different regions, trading ratio model (TRS)

Results: Proving the implementation of pollution trading implementation in the urban and industrail units wastewaters in Langeroud and offering the buy and selling plan among these units, traditional livestock laughter unit will produce 30 m^3/day, Langeroud urban sewage produces 15705 m^3/day and the tanning unit produces 18 m^3/day waste water daily.

Conclusions: The cost of Emissions trading differs between countries because the Marginal Abatement Cost Curve (MAC) — the cost of eliminating an additional unit of pollution — differs by country. It is expected that trade can only function and contribute to the improvement of water quality when it is considered a cheaper option, i.e. cheaper than the violation of a permit limit.

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Background

Water is essential for life and for all human activities but also for preserving the environment and its resources. Rapidly growing population, intensification of agriculture, industrialization, urbanization, development of any kind and climatic factors are the main reasons for water scarcity conditions in many countries of the world (1). Water crises, for instance, rank as the third highest concern from Ten Global Risks of Highest Concern in 2014 (2). Rivers are considered as one of the basic sources of water supply for survival of organisms for example are living place for fish and they are a place to discharge the civic sewages and industrial waste waters. Every river has somewhat the capacity to receive the entering contaminants (3).

One of the effective approaches for water quality management in river system is trading of discharge permits.

Recent decades, several models have been proposed for trading discharge permits in river Systems (4).

Implementation of pollution trade plan on the water supplies was started in 1996 with publication of its executional quidline drafit by US environmental protection administration (5) across its individual states among them Michigan pollution trade plan (6) and in internationally, implementation of pollution trade plan in catchment basin of Nanpen river China (7) and survey on implementing the same plan in Chile (8) can be mentioned Ayhart (2004) studied on the role played wastewater discharge licenses in defining the total maximum daily load and concluded using theoretical reasoning that licenses trading can be utilized as an important tool to design the TMDL plan reach a desirable equilibrium between economic efficiency and water quality. Total nitrogen trade plan in long Island in connection state (9).

Hung and Shaw (10) show that the TRS is an ideal trading system for water pollution control. It is a cost-effective instrument that meets predetermined environmental quality standards with the least aggregate abatement costs. It can avoid the well-known problems of high transaction costs resulting from assembling a portfolio of permits under the APS, high transaction costs arising from approving trades by simulating trades beforehand and free riding under the POS, and the possibility of violating the environmental quality standards under the ERS Mesbah, et al (11). developed a new technique to trade the pollution load discharge licenses by adding the phasic cost functions and by consideration of major uncertainties in the river. Efficiency of this technique in Zarjob river in guilan province was evaluated Nikoo, et al (12) used trading ratio system (TRS) for Bayesian network efficiency in the river water quality management. Based on this pollution load trading technique, it performs water quality management and estimates the pollution load discharge licenses trading in real time. Jafary, et al (13) developed the pollution trading using tradable discharge licenses in Dez river and its evaluation in respect of cost efficiency. For each emission unit, the pollution control costs were calculated technologically and non-technologically and technologic to non- technologic control ratio was studied as the criterion of cost efficiency of pollution exchange. Mesbah, et al (14) developed new model for trading the licenses for (BOD_5) pollution load discharge in the river. Such that water quality standards in the rivers are observed for dissolved oxygen concentration (DO) they also demonstrated that it is possible to precisely calculate the discharge license trading rate by training on Bayesian network.

In this paper, due to one-way flow of water in rivers Langrood, pollution trade theory and the system of Ratio-Trade (TRS) and Streeter - Phelps equation has been used. This system, with a view of the river self- purification and how the distribution and transport of pollutants, determined TRS between the units and using this method offers optimal pattern of pollution trade between emissions units. System-Trade model designed only for one type of pollution and in this research, TRS model had used. Performance of the proposed model using both quantitative and qualitative data of Langrood River located in Langrood town, Guilan evaluated.

The results demonstrate the efficiency of pollution trade policy on quality management of river. In the present case study, practicing pollution trading programs between two emissions units of traditional livestock slaughter and tanning and sales units, licensing agreement on the price of 20 million rials per ton with determined pollution and every year 6 million rials from the total annual cost for the construction of wastewater refinery for tanning unit returned. Due to 20% interest rate, the number of years for the return on investment for plant construction is calculated 12 years and then, the licenses of evacuation will be considered as the profit of tanning units.

Emissions trading or cap and trade is a market-based approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants (15).

Aims of the study: This study aims to investigate the water quality trading using tradable permit in biodiversity of river and assessment of efficiency of expense.

Materials & Methods

Generally implementation of pollution trading plan was performed using transmission coefficient in the study area in 5 stages (13).

In the following description of the concepts and formulation of each mentioned stage are provided.

Zonation of study area

Langeroud river area in present study was divided based on presence of major contaminating sources and monitoring stations to 3 regions as follows:

Region 1: From Metal bridge of Siahkalah to Vady station of Langeroud locating on the western part of Langeroud city with 5 km^2 area. The most important emission source in this limitation is Langeroud traditional livestock laughter considered as region 1.

Region 2: From Vady station of Langeroud to the tanning units locating in an area equal to 15 km^2 and is located in the western and northern part of Langeroud city. The most important emission unit in this area is the civil sewage discharging directly to the Langeroud river (Brick bridge) by channeling the sewage.

Region 3: From taning unit to the river mouth to the (Chamkhaleh) sea locating in the north Langeroud and its length is 10 km^2. The most emission unit this area is tanning unit which is considered as region 3.

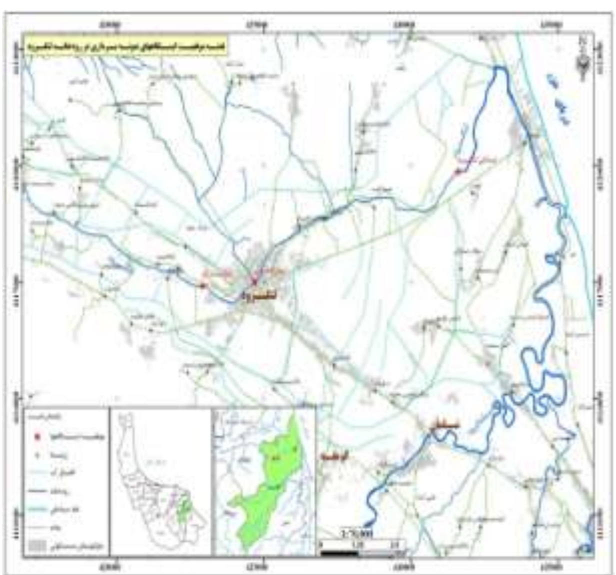

Figure 1: location of emission units in Langeroud river

Qualitative change in dissolved oxygen (DO) and biochemical oxygen demand BOD$_5$ alon Langeroud river in the existing conditions

Frequency of sampling and testing of water samples should allow precise control of water quality. For qualitative modeling, Langeroud river is divided to 9 sections based on the emission units and qualitative changes (table 1) samplings performed.

Samples measured in laboratory of water and wastewater pollution measurement of Guilan environmental administration. DOmeter hydro-bios Kiel model used to measure DO. DOmeter consists of a electrode where solution sample is preserved via a membrane permeable for oxygen. Oxygen reaches to the electrode by passing across the membrane and transmission occurs between the electrode and molecular oxygen. The reaction taking place in the cathode is as follows

$$O_{2\,(solution)} + 4H^+ + 4e^- \longrightarrow H_2O_{(L)}$$

Where molecular oxygen reacts through storing the hydrogen ion by a buffer solution available between the membrane. The reaction taking place in the anode is:

$$2p^{bo} \rightarrow 4e^- + 2p^{b2+} \quad \text{(solution)}$$

This electron transmission causes the current flow from electric current gauge. Current gauge consists of an ammeter and an electrode where current rate is proportionate to the dissolved oxygen rate in the sample (Shariaty, 2010) to measure the biochemical oxygen demand (BOD$_5$) we will take 10 ml wastewater sample them 1of each phosphate bulk solution (to preserve the PH) ma son, (to reinforce the microbes feeding) is added and solution volume is reached to 1 liter using distilled water. Then 250 ml of prepared solution is poured in a dark colored BOD container such that it is completely overflowed, then it is placed in an incubator for 5 days in 20 co. dissolved oxygen rate of remaining solution is measured by winkler technique or a dometer. It is recorded as DO$_2$. Thus, BOD rate of the sample is obtained via the following equation

$$\left(BOD_5\right) mg\ / \ l = \frac{Do_1 - Do_2}{p}$$

P = dilution factor (here 0.01)

Table 1: Name of the sampling stations in the river Langerood

Row	Station name	DO(mg/lit)	BOD_5 mg/lit	GPS(UTM)
1	Siahkalah	1.73	2	418813E 4118330N
2	langgeroud river-over the slaughterhouse	1.47	16	422431E 4116998N
3	Traditional live stock laughter	0	650	422916E 4116916N
4	langgeroud river-lower the slaughterhouse	0.712	43	423413E 4116667N
5	vady station of Langeroud	1.54	15	424131E 4116578N
6	brick bridge	0.71	98	424735E 4117035N
7	Anzali neighborhood	0.94	22	425745E 4117712N
8	Tanning units	0	4600	431517E 4119765N
9	Sea estuaries	2.95	19	435594E 4119067N

Defining the total standard output load of each region and initial assignment between the emission sources

The standard output rate for each region or emission unit is estimated according to the water quality standards in the given area. In this study permittable contamination load for emission units in the study area is defined based on BOD_5. BOD_5 index in addition to being shared between all the emission units, causes to decrease in Do in the river. Additionally this criterion is proportional to the demand and supply of emission units as seller and buyer in respect of suitable discharge time (16).
To define the permissible load rate for each emission unit, the qualitative simulation model for rivers been formulated for BOD_5 - DO based on streeter – phelps relations (Jaefary, et al 2008)
Strreter – phelps relation (1) (Jaefary, et al, 2008)

$$D = \frac{k_c.k_{co}}{k_2 - k_c}\left(e^{-kc} - e^{-k_2}t\right) + Do.e - k_2 t$$

Where D represents the oxygen deficiency rate compared to the saturation, K_c is equal to the BOD_5 deterioration rate per (L/day) K_c is aeration coefficient and t is the arrival time from the origin to the given point.
In present study, the suitable qualitative class in the qualitative standard of the river was used based on the standard of environmental protection administration in Iran. According to this standard do allowable limit to discharge to the surface waters is 2 mg/l and the maximum BOD_5 in the river is 50 mg/l.

Defining the transmission coefficients between the emission units and different regions

In general, transmission coefficient implies the percentage of pollution load transmitted from upside after passing a distance which according to its application in the pollution trading it is studied from 3 aspects:
- Between the terminal stations of defined regions
Between the emission units existing in a region or different regions –
From emission units to the terminal stations of the regions locating in it. –
The first one is used to evaluate the transmittable allowed load rate in each region and to facilitate the monitoring and surveillance by environmental conservation Administration, the second one is utilized to facilitate the exchange of discharge licenses issued between various emission units and the third one is utilized to evaluate the contribution of each emission unit of total licenses allocated for the region locating in it.
According to the definition, transmission coefficient a_{ij}[8] is contribution of discharger (region) I in the output pollution load the discharger (region) it is always a number between 0 to 1 the equation (2) represents this concept (5)

$$a_{ij} = \frac{L_j}{L_i}$$

Where
L_i = pollution load of it discharger (region) (upside)
L_j = pollution load of j_{th} discharger (region) (down side)

Trading – ratio system (TRS)

In the river system, since the water current is unidirectional, trading – ratio system developed by Hang & Show (10) can be used to control the polluting units. This system will define the trading-ratio between the units, taken in to account the self

– purification rate of the river and distribution and transmission of contaminant and then offers the optimum pattern of pollution trading. TRS system has 3 prominent characteristics, including : pollution load perception capacity of each region which is calculating by taking the load transmitting from upside regions, Pollution trading coefficients between the regions defining according to the transmission coefficient, Trading the discharge licenses between the units in addition to observation of environmental standards, will decrease the total cost of the system (12) in the trade – ratio system it is required that the river is divided to some regions where the first regions is located in upside area (10) environmental conservation organization defines each regions acceptation capacity E_1 based on the water quality standard for that variable (s) and according to the major usage of that region. The river pollution load acceptance capacity in each region is equal to the maximum pollution load rate which can be discharged in the outset of the region providing that water quality along the region doesn't deviate the standard. Environmental organization defines the tradable discharge allowable rate in each area (TDP) from up side to downside, respectively. Allocation of these rates is defined taken the pollution load capacity of considered region and pollution transmission rate is defined from upside regions. Equations 3 to 6 indicate TDP calculation technique (10).

To obtain the exchangeable discharge allowable rate in the region 1 TDP_1 equal to the output allowable load rate in the region, E_1 is calculated according to the equation (3)

$$TDP_1 = E_1$$

To obtain allowable rates exchangeable discharge in the region 2 TDP_2 it is calculated by derivation of the values obtained by output allowable load from downside region E_2 with the values obtained from exchangeable discharge of allowable load in the region 1 in the upside ($a_{12}\,TDP_c$) (10).

$$TDP_2 = E_2 - a_{12} TDP_1$$

$$TDP_3 = E_3 - a_{13} TDP_1 - a_{23} TDP_2$$

And in general equation (6) is used to obtain tradable pollution discharge allowable load (TDP_j) (10).

$$TDP_j = E_j - \sum_{k=1}^{j-1} a_{kj} . TDP_k$$

$$k < j$$

Where (TDP_j) exchangeable discharge allowable load from region j (emission unit i)

Ej= allowable load discharging from region j (emission unit j)

a_{kj} = transmission coefficient from the region k locating in upside of regions j

If in the region j the value of $E_{j-1}\ a_{(j-1)j}$ in larger than Ej, this region is called critical region. In this case equation 7 is used to define the (TDP_{j-1}) value (4).

$$TDP_{j-1} = \frac{E_j}{a_{(j-1)j}} - \sum_{k=1}^{j-2} a_{kj} . TDP_k$$

Environment organization defines the allowable rate of discharge for each unit, based on the allowable rate of exchange in the region (TDP_j). It is suggested that in each region there is only one emission unit. But if there is more than 1 emission units in the region, it is assumed that allowable rate of exchange in that region is divided between the units equally (12).

Emission units pollution control cost

To study the cost efficiency in the pollution trading it is required to estimate the costs of refinery plant construction and the tradable permits performance costs studying in the following. Along the Langeroud river there is 3 emission units including a traditional livestock laughter, Langeroud civic sewage and the tanning unit. To obtain the allowable rate of tradable discharge in each region (TDP_j), it is required to know the wastewater volume produced by emission units per mm/d and biochemical oxygen demand rate (BOD_5).

Urban and industrial refinery plant construction cost

The cost of construction of urban and industrial wastewater refining plants varies depending on the nature and volume of produced wastewater, the kind of process the refinement degree. In present study, with studies performed in the current projects for civil sewage system (world bank projects, 2012) across the provinces and as study hypothesis, for construction of industrial waste water treatment plant, about 20 million rials/mm refinement per day was assumed. For construction of urban wastewater treatment plant, 10 million rials/mm assumed and the plant lifetime considered 25 years. In addition, in this study, the exploitation cost considered 3% of annual cost for industrial refinery plants and 2% for urban refinery plants.

The costs of implementing the pollution trade exchange plan

The costs of implementing this plan trough exchange ratios is including two major parts. Implementation and monitoring costs for tradable permits are estimated proportional to the expansion and importance of the plan range and the kind of measures per year. Finally, mean cost of each tone of pollution decrease for environment conservation organization can be the basis to determine the initial cost of discharge permits selling to the emission units depending on the kind of their contribution. This way the annual costs implementation and monitoring will be returned.

Results

Table 2: Transmission coefficient matrices between the regions in the study area (Hung & Shaw, 2005)

Regions	Regions (unit)1	Region (unit) 2	Region (unit) 3
Region 1	1	0.64	0.52
Region 2	0	1	0.77
Region 3	0	0	1

Table 3: Trans mission coefficient matrices between the polluting units in the study area (Hung & Shaw, 2005)

Polluting units	Live stock laughter (unit)	Langeroud city (unit)	Taning units
Traditional live stock laughter	1	0.64	0.52
Langeroud city	0	1	0.77
Tanning units	0	0	1

Discussion

In table (2) the first kind of transmission coefficient matrices (transmission from each region to the down side region) and in the table (3) the second kind of transmission coefficient matrices (transmission from an emission units to another down side emission units (s) are given. These coefficients have been utilized in the next stops to evaluate the allowable discharge rate from a region to the down side region and to define the ratios of tradable discharge permits exchange between polluting units (4) in the following tables, transmission coefficient form upside to down side polluting sources was set as zero.

The investment and operation costs and their annual equivalents were calculated given the equation (8) and results are indicated in table (5) the costs of pollution trading plan implementation and monitoring by environmental conservation organization. During the study performed in the urban sewage system relating to the World Bank projects in 1391, in average the cost of each tone pollution decrease for this organization is 700.000 rials. Thus, it is possible to consider the initial cost basis for discharge permits to sell to the emission units depending on their contribution ration.

Cost efficiency of the plan to exchange the ratio of treatment plant construction cost to the pollution treatable permits (c_1/c_2) is defined in 5 classes including very high efficiency (0- 25) high (25-50) average (50-75) low (75-100) and very low (more than 100) the more cost efficiency represents more economic benefit for specific emission units to construct the treatment plant and to sell discharge permits in the pollution trade market and vice versa the low cost efficiency indicates the tendency of emission units to buy the permit instead of constructing a treatment plant.

Table 4: Defining the TDP of the regions based on allowable pollution load of emission units of each region

region number	Source name	Wastewater produced (m/day)	BOD_5 (mg/lit)	Pollution load (ton)	Pollution discharge allowable load (ton/y)	Ej	TDP region (ton/y)
1	Traditional live stock laughter	30	650	7.2	0.5	0.5	0.5
2	Langeroud city	15704	98	562	276.5	386.5	220
3	Tanning unit	18	3600	30	0.3	0.3	0

Table 5: Estimating the annual cost of constructing the contaminant sources refinery plants in the study area in 2012

region number	Emission source	cost to construct the refinery plant (million rials)	Annual cost of initial investment (million rials)	Annual exploitation cost (million rials)	Total costs of annual investment and explotation (million rials)
1	Traditional livestock laughter	600	120	3.6	123.6
2	Langroud city	15040	31408	629	32037
3	Tanning unit	360	72	3	75

Table 6: Comparing the cost efficiency to control the contamination for various emission units through refinement and tradable permits in 2012

region number	The emission units name	The required load decrease (tone/year)	The cost of annual trable permits control (c1) million rial	The annual cost of refinery plant control (c2) million rials	C2/c1	Cost efficiency
1	Tradition livestock laughter	6.7	4.7	123.6	26.2	Up
2	Langeroud city	275	192	32037	166.8	Very down
3	Tanning units	7.29	20.7	75	3.6	Very up

Cost efficiency values in table (6) indicate that for tanning units, the cost of constructing the treatment plant has not significant difference to their tradable permits costs. Very much cost efficiency and treatment plant construction in perfences according to its economic aspects on one hand, investment costs will be returned after a given period through selling discharge permits. On the other hand, construction of treatment plant is a permanent technique which performed once at least 25 years (life time of a treatment plant) while tradable permits are temporary (1 year) for other emission units such as traditional live stock laughter and langeroud city sewage with low cost efficiency buying the discharge permit from other emission units is preferred instead of constructing a treatment plant.

The maximum price these units agree to pay for buying these permits is equal to the cost of construction of a treatment plant. The prices of buying and selling these permits depend eventually to the bargaining power of the two parties between these two limits. For example, two emissions units including traditional live stock laughter and tanning units will enter the exchange due to "high" cost efficiency for the first one and "very high" cost efficiency for the second one. So:

The total pollution load measured in the region 1 where livestock laughter is located must not be higher than TDP13 determined for that region i.e TDP = 0.5 tone (table 4).

The cost of each tone of pollution load is equal to the total annual costs of construction of treatment plant and the cost of buying the discharge permits ratio to the required decrease in pollution load per year. For tanning unit, this cost for constructing a treatment plant is 75 ÷ 7.29= 10.2 million rials/tone pollutions load. Certainly, this unit is not inclined to sell the permit of each tone of its pollution lower than this price. This cost for live stock unit will be 123.6 ÷ 6.7=18.4 million rials/tone pollution load if it wants to construct a livestock laughter unit. It is inclined to buy the required permits deficit to reach the discharge allowable limit (0.5) maximum by this price (per each) unit.

Wastewater transmission coefficient of live stock laughter to the tanning unit according to the table (3) is 0.52 unit i.e. in exchange of buying one permit from tanning units, it is permitted to discharge 1.92 tones of pollutions. Since 52% of its pollution to reach the tanning unit will decrease due to self – purification of the river. On the other hand, the tanning unit can sell all its discharge permits (0.3 tones) to the livestock units its pollution load decreased to the amounts lowers then determined limit. So live stock unit, by purchasing 0.3 tones of permit unit from tanning unit, can discharge 1.92× 0.3= 0.576 tones of pollution load in excess of the initial allowable value. Thus, pollution load existing in the terminal region due to discharge of live stock laughter by purchasing the discharge permits from the tanning unit and using its own ration will be totally equal to the allowable discharge (0.576) equal to 1.07 tone.

Assuming equal to 20 million rials/tones, the tanning unit can return annually 20× 0.3=6 million rials of its total annual cost of treatment plant construction (75 million rials) thus according to the 20% interest rate, using equation (8) the number of initial investment return years for construction of treatment plant is 12 years and there after the discharge permits selling will be considered as the profit of tanning unit. Obviously the more expensive the tanning unit Langeroud could sell its permits, its investment return will be higher and the sooner it will get benefit.

To obtain the comparison criteria and taking into account the investment and operation costs. Emission units pollution control cost is calculated based on the equivalent annual costs using equation (8) (5).

$$A = P\left(\frac{i\,(1+i)^N}{(1+i)^n - 1}\right)$$

It is worth mentioning that the exchange in other regions and pollution discharging units similar to the above mentioned cases is repeatable and approvable in the mentioned order.

Conclusions

In present study, usage of pollution trading theory as one of efficient tools to qualitative management of the river was provided to control and decrease the pollution of Langeroud river. Efficiency of the river qualitative management plan is dependent on providing the effective strategies for decreasing and controlling the pollutions with minimum costs. Taking the stages of pollution trading plan formulation after zonation of study area and characteristics of emission units the rivers qualitative model based on streeter- phelps model was used to determine the standard load output of each region the coefficient of pollution transmission from qualitative model of river. Finally by calculation of exchangeable pollution load in each region. it was examined according to the transmission coefficient as a sample. The results indicate that tradable permits implementation is an efficient technique to preserve the biodiversity for urban emission units due to the heavy price of treatment plant construction from one hand and for industrial emission units according to the costs of treatment plant construction through selling the discharge permits. In additions, this technique has higher efficiency and cost for environment organization due to decrease in monitoring costs and decreasing the delay to reach the allowable limit of emissions units pollutions. Efficiency rate of this technique depend on the number and rate of possible exchanges in each region and in total study area. The greatest exchanges will occur among the large emission units (such as tanning units) as the seller and the small emission units (such as traditional livestock Langhter) as buyer. Such that by implementing the pollution trading plan among the emission units, dissolved oxygen rate in Langeroud river will reach from zero to the standard limit of environment organization i.e. during 12 years.

Proving the implementation of pollution trading implementation in the urban and industrial units wastewaters in Langeroud and offering the buy and selling plan among these units, traditional livestock laughter unit will produce 30 m^3/day, Langeroud urban sewage produces 15705 m^3/day and the tanning unit produces 18 m^3/day waste water daily. This amount of wastewater with execution of technical principles and construction of treatment plant according to wastewater output standard of environmental organization (legal bureau and council affairs, 2004) the biochemical oxygen demand BOD_5 and dissolved oxygen (DO) before and after the implementation pollution, trading plan is as table 9. BOD_5 in the traditional livestock laughter wastewater was 650 mg/lit and DO rate was zero. Tanning unit by implementing the pollution trading plan and buying the discharge permit, can discharge 1.076 tones pollution annually and 52% of traditional live stock laughter pollution load will be removed due to the river self – purification until reaching the tanning unit. But in the tanning unit, BOD_5 value was 4500 mg/l which upon the construction of treatment plant according to the standard wastewater output of environmental conservation organization BOD_5 value much reach to 50 mg/l and amount of DO according to the environmental organization must reach to 2 mg/ l.

Footnotes

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