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Assessment and Upgrading of Khoy Wastewater Treatment Plant

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Abstract: This research contains assessment and analysis of the operation data for 30 months, analysis of 540 checklists results to determine design parameters, redesigning the WWTP to determines the problem agents and upgrading requirements, designing the various processes for upgrading and evaluating them by molt-criteria decision and selecting the most proper alternative. The results show that the main true design parameters such as BOD_5 and TSS are 50 and 57 g/capita-day, respectively. The water consumption and wastewater production per capita per were 220 and 187, respectively. Using these Design criteria to come up with the best alternative for upgrading of wastewater treatment plant a number of remarks such as: ease of O and M, low operational costs, low maintenance costs, low capital costs short implementation period, potential to remove N and P, reliability of performance, innovation, pollution prevention, maximum use of facilities, long useful life and minimal plant disruptions were considered. All of the alternatives were evaluated by multi-criteria decision method. The score earned by various alternatives are: Use of rock filter in maturation pond effluent (-59), Use of micro strainers for filtration the effluent (-38), Dual powered aerated logoon (-65), Activated Sludge with digest and store excess sludge countercurrent with part of influent wastewater about 8500 m^3 day^{-1} in available lagoons (196), Commutation of No. 1 lagoon to aeration tank and built the sedimentation tanks, invert it to extended aeration tank and use the No. 2 and 3 lagoons for sludge storing (241), Biolac Process (201), Facultative aerated lagoon in 3 modules (-107). At last the alternative with highest score was selected.

Key words: Aerated lagoons, cold climate, multi-criteria, efficiency

INTRODUCTION

Upgrading of wastewater treatment facility may be necessary to meet the existing effluent quality and/or to meet the stricter future effluent quality requirement and/or to enhance its capacity because of population growth or sewer network expanding to serve more areas. An inability to meet the existing effluent quality may result from lack of proper plant operation and control, inadequate plant design and increased hydraulic or organic loading caused by a change in wastewater flow or characteristics (Qasim, 1999).

Under such requirements, additional treatment process such as process modification, filtration, rock filter, carbon adsorption, chemical precipitation, wetlands, micro strainers, equalization ponds or tanks, modifying flow pattern, alternate or modifying inefficient units and etc my be necessary (Metcalf and Eddy, 2003; Qasim, 1999).

The city of Khoy is located at the northwest of Iran, that is a cold climate region. The first module of the Khoy WWTP was designed in 3 modules that its firs module was constructed to serve 70,000 inhabitants and its process is facultative aerated lagoon, but the population of Khoy at present equal to 180,000 persons. Because of incompatibility of lagoon base systems with cold climate, its efficiency decreases in cold months and exceeds from discharge standards, furthermore because of population growth and network expanding, it is necessary to upgrade this WWTP both in quality improvement and capacity increasing.

Prior to this research some various alternatives has been evaluated and used for upgrading the natural based WWTPs both for enhancing their capacity and effluent quality. Some of these alternatives include: Using the rock filter in Kansas, Veneta, Oregon, Eudora (USEPA, 1983a; O'Brien *et al.*, 1979) using micro strainers in Camden, using wetland systems in Monteroy, VA,

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Carville, LA, Hardin, KY, Greenleaves, LA (Reed, 1993) Intermittent sand filtration in south Carolina and Georgia (Rich *et al*., 1990), Upgrading of Albama WWTP by Hyacinth (Mcanally, 1990).

In this research an engineering evaluation has been carried out in design and performance of this WWTP, in order to identify cost-effective strategies for using the existing treatment facilities to meet these additional treatment efficiency and increasing it's capacity. Based on engineering evaluations, it appears that necessary additional treatment and capacity increasing can be achieved by some modifications of existing facilities in aeration system, sedimentation and increasing MLSS of aeration tank and modifying the channels and weirs. These changes may be sufficient to achieve the necessary quality and upgrading the system capacity, without construction the other 2 modules.

The objectives of this study were:

- To determine the exist system performance
- To determine exist system problems and their reasons
- To compute design parameters for upgrading the WWTP
- To select and design an optimum alternative for Upgrading the exist WWTP.

MATERIALS AND METHODS

During February 2004 to may 2004, all ponds were sampled from sampling ports that were signed on Fig. 1 and several physical, chemical and biochemical parameters such as BOD_5, COD, TSS, T°C, free chlorine residual, pH, DO were analyzed, following standard methods for examinations of water and wastewater (APHA., AWWA. and WPCF., 1992).

Site description: This WWTP serves about 70000 inhabitants and is composed of 4 ponds in series, that 3 of them are facultative aerated lagoons, which followed by a maturation pond. The area of each lagoon is 1690 m^2 and its liquid depth is 3.5 m and each lagoon volume equal to 44600 m^3. The area, depth and volume of maturation pond is 38400 m^2, 1.8 m, 55000 m^3. It uses 12 surface aerator (15 kw) in lagoon No. 1 and 9 surface aerators (11 kw) in lagoon No. 2 and 9 surface aerators (7.5 kw) in lagoon No. 3. The chlorination system derived from: (1) Chlorination building with tow tanks for mixing and preparation stock solution for injection to effluent with five dosing pumps. (2) Two chlorine contact basins with total depth = 3 m, length = 15 m, width = 10 m and number of baffles = 7.

Exists system performance: For assessment the efficiency in cold climate the operation examinations during three years (2001 to 2004) were evaluated.

To compute design factors: Results from sampling examinations during study period and lately 36 month operation and the results of checklists have been assessed.

After calculation the true design parameters for determination exist system defaults and upgrading requirement places, exist system redesigned based on revised parameters. Accordingly all of exist system component include pump station, bar screens, Parshal

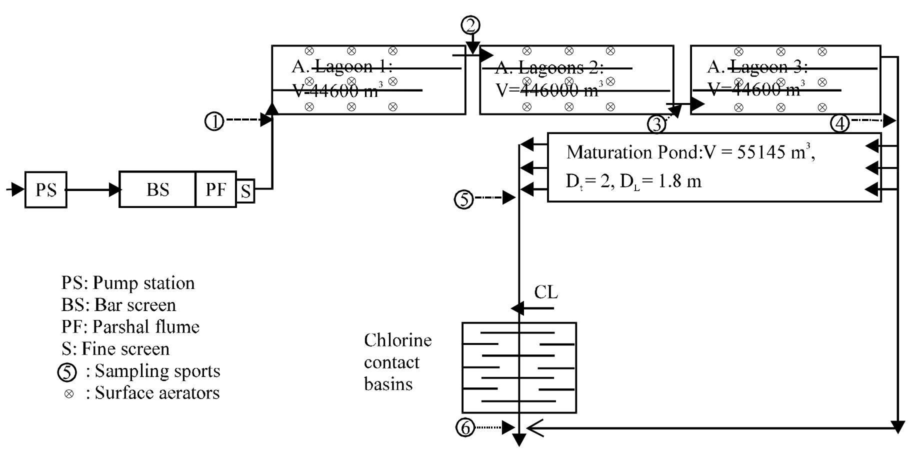

Fig. 1: Flow sheet: originally existing wastewater treatment plant

flumes, aerated lagoons, maturation pond, disinfection's system, conduit canals and weirs were been redesigned.

Pump station redesign were done based on detention time and flow velocity in wet-well, So bellow equation has been used: (Programming and Management Organization, 1993).

Wastewater pump stations: $V = \theta q/4$

(θ) = Interval time between each starting of pumps,
(q) = Capacity of pump.

Aerated lagoons have been redesigned with EPA method that for determination the K_c, the wastewater temperature in lagoons for various climate conditions has been computed. which summarized as below equation (Lee and Shun, 2002; USEPA, 1983a).

$$T_w = \frac{AfT_a + QT_i}{Af + Q} \quad , K_{c_T} = K_{C_{20}} \theta^{(T_w - 20)} \quad , \frac{S_n}{S_0} = \frac{1}{\left[\frac{K_c t}{n} + 1\right]^n}$$

Redesign of maturation pond has been done based on plug flow model and Marais and Show method, which summarized as below equation: (Metcalf and Eddy, 2003; USEPA, 1983b):

$$\frac{C_0}{C_n} = 1 + K_c t \quad , \frac{D}{UL} = \frac{Dt}{L^2}$$

Alternatives design: This part of research emphasizes on three objects include: (1) Achieving to better effluent quality (2) Countercurrent upgrading in effluent quality and capacity (3) Upgrading the system's capacity. Alternatives are: (a) Using Rock filter in maturation pond effluent for removal TSS and to some extent BOD_5 removal, (b) Using Micro strainers for filtration exist system effluent. And alternatives which comply for countercurrent upgrading of efficiency and capacity are: (c) Dual powered aerated lagoon, (d) Activated sludge system that digestion and storing of excess sludge accomplish with a part of influent wastewater (8500 m^3 day^{-1}) in exist lagoons. (e) Commutation the No. 1 lagoon to aeration tank and built the sedimentation tanks, invert it to extended aeration tank and use the No. 2, 3 lagoons for sludge storing, (f) BIOLAC process, (g) The exist scheme (construction another 2 module parallel with exist module) which this alternative only increases the capacity of WWTP.

For comparison the upgrading alternatives and selection the best choice, the foregoing alternatives were comprised based on 11 factors, which 5 factors of them evaluated by negative scores and 6 of them evaluated by positive scores. The negative score parameters are: Capital costs (9), Cost of O and M (8), Implementation period (3), Plant disruption (10) and Land requirement (5). The positive score parameters are: Potential to alter the process for advanced treatment in N and P removal (10), Countercurrent upgrading in capacity and efficiency (10), Flexibility in operation for various condition (10), Reliability of performance (9), Maximum use of exist facilities (5), Innovation (5).

RESULTS AND DISCUSSION

Assessment exist system performance: System efficiency in warm seasons was favorable but in cold months the level of contaminants concentration in effluent were been higher than discharge standards. (Fig. 2). That the strong correlation observed between WWTP efficiency and temperature and effect of decreasing in air temperature was very critical. Also about TSS removal rate, there are two another nonconformity in spring and autumn seasons and in these periods of year the TSS concentration in effluent increases because occurring decertification in maturation pond and re-floatation of settled solid in the pond's bottom.

For determination the efficiency the examination results of sampling during this research and 36 monthly operation results examination has been evaluated. In Fig. 2 the concentration of BOD_5, TSS in effluent during mentioned periods demonstrate.

Computation design factors: The comparison of exist system design parameters and new resulted parameters for upgrading during this research is demonstrated in Table 1. There is not significant differences between these parameters, therefore the exist system problems doesn't refer to design parameters.

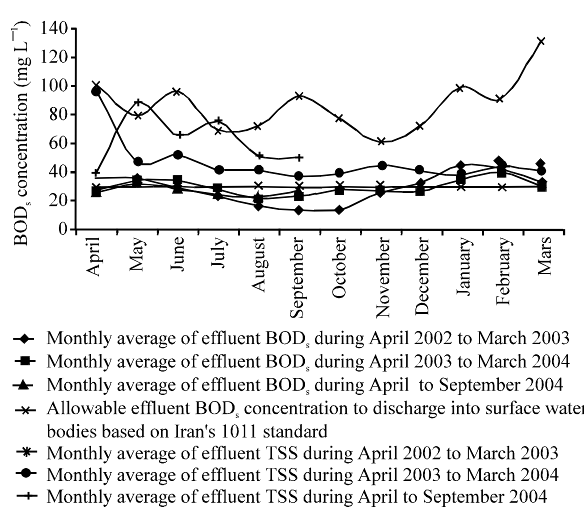

Fig. 2: Variation in effluent BOD_5 and TSS during April 2001 to September 2004

Table 1: Comparison the calculated design parameters with exist system parameters

Parameter	Unit	Value	
		Upgraded parameters	Initial parameters
Public service and commercial wastewater	LPCDa	13	-
Public service and commercial water	LPCD	16.25	-
Municipal water consumption at 2001	LPCD	189	-
Design year	-	2031	2031
Growth rate in water consumption per year	LPCD	1	-
Ratio of discharge the produced wastewater into sewer	Percent	82	
Water consumption in design year	LPCD	220	200
Infiltration	LPCD	15	33
Wastewater produced in design year	LPCD	191	197
Estimated population at design year	Persons	220,000	221,300
Average wastewater flow rate at design year	$m^3\ d^{-1}$	41,800	43,598
BOD_5 produced	$g\ c^{-1}\ d^b$	50	50
BOD_5 concentration	mg L	260	250
Influent organic loading	$kg\ d^{-1}$	2090	2178
Minimum temperature that system designed based on	°C	-5	-

a = Litter per capita per day, b = Grams per capita per day

Table 2: Multicriteria evaluation of alternatives for determining the designee choice

Parameters	Upgrading choices						
	Choice (a)	Choice (b)	Choice (c)	Choice (d)	Choice (e)	Choice (f)	Choice (g)
Capital costs (-)	3	4	8	9	7	8	6
	9	9	9	9	9	9	**9**
Costs of O and M (-)	3	4	5	9	7	6	6
	8	8	8	8	8	8	**8**
Implementation period (-)	2	1	7	7	4	5	8
	3	3	3	3	3	3	**3**
Potential to alter the process	1	1	2	9	9	9	2
for advanced treatment in P	10	10	10	10	10	10	**10**
and N removal (+)							
Countercurrent upgrading in	2	3	3	9	9	9	2
Capacity and efficiency (+)	10	10	10	10	10	10	**10**
Flexibility in operation for	1	2	2	10	10	9	1
various condition (+)	10	10	10	10	10	10	**10**
Reliability of performance (+)	2	2	2	10	10	9	1
	9	9	9	9	9	9	**9**
Maximum use of facilities (+)	5	5	4	2	10	9	4
	5	5	5	5	5	5	**5**
Innovation (+)	2	3	5	7	8	7	1
	5	5	5	5	5	5	**5**
Plant disruption (-)	5	4	3	1	6	7	2
	10	10	10	10	10	10	**10**
Land requirement (-)	9	9	7	7	4	5	9
	5	5	5	5	5	5	**5**
Sum (+)	93	118	133	415	460	431	84
Sum (-)	152	156	198	219	219	230	**191**
Difference	-59	-38	-65	196	241	201	-107

(-): negative score; (+): positive score; a) Using Rock filter in maturation pond effluent for removal TSS and to some extent BOD_5 removal, b) Using Micro strainers for filtration exist system effluent. And alternatives which comply for countercurrent upgrading of efficiency and capacity are: c) Dual powered aerated lagoon, d) Activated sludge system that digestion and storing of excess sludge accomplish with a part of influent wastewater (8500 m^3/d) in exist lagoons. e) Commutation the No.1 lagoon to aeration tank and built the sedimentation tanks, invert it to extended aeration tank and use the No. 2, 3 lagoons for sludge storing, f) BIOLAC process, g) The exist scheme [construction another 2 module parallel with exist module] which this alternative only increases the capacity of WWTP

Redesigning the exist system: For determining the possible defaults and their accommodations with upgraded system requirement all parts of exist system has been redesigned. Based on revised design parameters, Parshal flume, Bar screen, Chlorine contact basin and most of conduit canals are acceptable in them present form. But it is necessary to modify the pump station and aerated lagoons.

Pump station: Total volume of wet chamber is 900 m^2, but since the influent pipe altitude is so high from chamber bottom, the beneficial volume was limited to 100 m^3, that in the end of scheme period the detention time at average daily flow rate will be 3.5 min. Therefore the wet chamber volume isn't suitable therefore some Modification in tank shape and hydraulics and installation the bar screen for debarment clogging and damage of pumps are required.

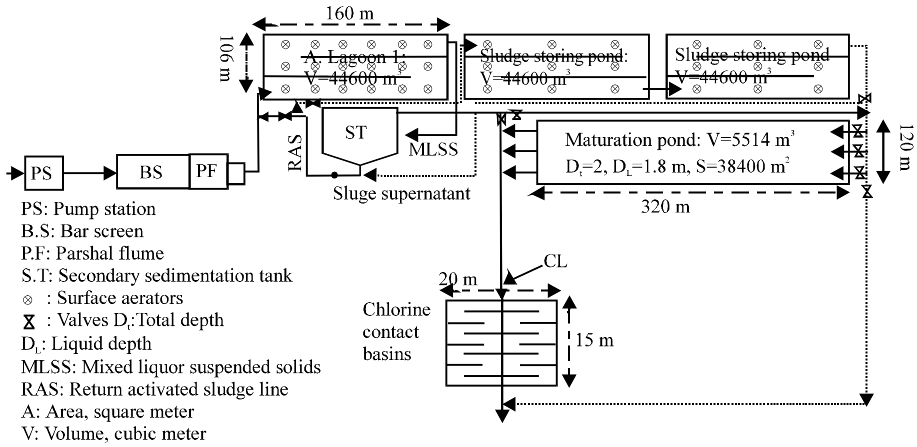

Fig 3: Flow sheet: upgraded wastewater treatment plant (designee alternative)

Aerated lagoons: As respects the examinations demonstrate the exist treatment operation can not able to obtain the conformity with surface water discharge tankards specially in cold months, but for determination the conformity of exist process performance with design parameters, the exist process redesigned and its results demonstrated that the system's performance have a acute dependence to ambient temperature, for example at -5°C the maximum wastewater which will be treatable by using this process is 6500 m^3 day^{-1}. Therefore exist system must be upgraded for comply with flow increasing and discharge requirements strengthening.

Determining the upgrading alternatives: Seven processes with notice to compatibility of them with exist facility and installations has been evaluated and designed, so from results of engineering evaluations each alternative assessed by Multicriteria matrix method in Table 2. The score earned by various alternatives are: a = (-59), b = (-38), c = (-65), d = (196), e = (241), f = (201), g = (-107).

DISCUSSION

It was found that environmental factors have a decisive effect over aerated lagoons efficiency in BOD and TSS removal. One of the most important factors is the temperature that is a linear relation between air temperature and lagoons efficiency.

From redesigning of exist system it was found that in the process selection and design of lagoons, there is not notice to the environmental factors specially ambient air temperature and the temperature variations in ponds properly. Therefore it is proposed that in design of biological process at cold climate regions, it is necessary to notice the minimum air temperature as a critical parameter.

Therefore with notice mentioned issues the designee choice for upgrading is:

1. Process commutation and alter available system to modified extended aeration by increase the MLSS in first lagoon and use the No. 2, 3 lagoons for sludge processing
2. Use the box screen on the influent pump station
3. Alternate available pumps with wet-dry pumps
4. Remove the screen after parshal flume
5. Alter the lagoons effluent weirs. The flow sheep of upgrading scheme with designee alternative was demonstrated on Fig. 3.

This process need less land and resists on cold temperature, organic and hydraulic shocks and can be used as a nutrient removal system and may be suitable for application in upgrading exist lagoons where a high quality effluent is mandated at all times.

At present time the mentioned project implementation is in the stage of contractor selecting. Finally the authors propose that some investigation and researches carry out in assessment and determination the microbial growth coefficients in various lagoons and its relation with suspended solids concentration in lagoons also researches on possibility the upgrading lagoons to nutrient removal.

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