Seasonal evaluation of the effluent quality of the Rosarito, Mexico wastewater treatment plant and identification of alternatives for its indirect reuse

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Abstract

This project addressed the problem of reusing treated wastewater, which is a common practice in the European Union, the United States, Canada, and some parts of Africa. The reuse of treated wastewater is not common in Mexico, and the majority of such water is discharged into the ocean and, to a lesser extent, on land. Because the reuse of this resource depends to a large extent on the quality of the treatment plant discharge, in this study we attempted to evaluate seasonal fluctuations in the quality of the Rosarito Norte treatment facility effluent over the course of one year. The majority of the total dissolved solids were found to consist of chlorides and sulfates such as sodium salts. Also reflected in the overall level of water hardness were salts derived from calcium and magnesium, as well as the carbonates and bicarbonates. These salts were not evaluated in this part of the project, but deserve consideration. The quantity of organic material was minimal with respect to BOD_5 (not up to 270 mg/L), and did not present a problem for the reuse of treated wastewater. The majority of the nitrogen present (TKN: 1.9-86.3 mg/L) was found to consist of proteins that remained as a result of the short curing time, as well as the poor oxygenation during the treatment process. Also present were high levels of total phosphorus and sulfates, between 15.5-38.2 mg/L and 197-1200 mg/L, respectively. The microbiological and parasitic analyses yielded excellent results, testing positive in only 33% and 0% of the trials, respectively. These results were compared with data reported for the aquifer into which the water will be infiltrated, and will be shared with the Tijuana office of the State Commission of Services for use as a basis for making decisions regarding the reuse of treated potable water.

Keywords: wastewater, reuse, indirect reuse.

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1 Introduction

Although the reuse of treated wastewater is still relatively rare in Mexico, with the majority of such water being discharged into the ocean and to a lesser extent on land [1], the problem of reusing this resource has become increasingly urgent in recent decades.

It is important to take advantage of the fact that the Northwest region of the country, particularly Tijuana and Playas de Rosarito Mexico, has sewer system coverage of slightly over 80%. In addition to its current use for irrigation, the collected wastewater could also be used to indirectly recharge aquifers, thereby augmenting the supply of potable water available to the region [2].

This practice is used the US, in states including California, New Jersey, and Georgia, where the underground water supplies are replenished with treated wastewater. In the coastal region of California's Orange County, treated wastewater is injected into the subsoil to help prevent the local aquifer from becoming contaminated by saltwater.

The county of Los Angeles has been using surface dispersion to recharge local aquifers since the 1960s. The city of Perth Amboy in New Jersey maintains two open reservoirs to replenish the local aquifer and to help protect it from the intrusion of salt water. The state of Georgia's Clayton County applies uses recycled wastewater to its watershed [3].

It is clear that the indirect reuse of treated wastewater is a viable alternative for helping to guarantee an adequate water supply to our region, and this option is included in the *Plan Maestro de Agua Potable y Saneamiento de Tijuana y Playas de Rosarito 2003* [4], the document describing the plan of the State Commission of Public Services to provide water to the cities of Tijuana and Playas de Rosarito.

One of the main objections to the reuse of treated wastewater is the lack of sufficient information regarding the current quality of the wastewater treatment plant effluent.

The present study addresses this issue by providing a seasonal evaluation of the physicochemical, organic, and biological properties of the Rosarito Norte wastewater treatment plant effluent for the purpose of identifying alternatives for indirect reuse.

2 Site of the study

Considering that the quality of the water treatment plant effluent is the factor limiting its reuse, it is necessary to determine the seasonal variation in the quality of the effluent originating from the treatment plants thought to be most efficient, as is the case with the *Planta de Tratamiento de Agua Residual de Rosarito Norte* (PTARRN), a wastewater treatment facility located in city of Playas de Rosarito at 12^0 22′ 21″ N and 116^0 54′ 15″ (see figure 1 [5]).

Figure 1: Site of the study.

3 Materials and methods

The collection and preservation of the water samples were carried out by personnel of the State Commission of Public Services of Tijuana in accordance with the government standards outlined in NMX-AA-003 [6].

The laboratory work consisted of an analysis of 36 samples composed of effluent taken from the North Rosarito plant (PTARRN) during the period from November 2006 to December 2007. The analyses performed on each sample included six physical, six microbiological, and 20 chemical. Each of these analyses was carried out and replicated at ISO 9001:2000 certified laboratories at the University of Baja California's Tijuana campus.

The analysis of 25 pesticides, 55 volatile, and 16 semivolatile organic compounds were carried out using methods established by the US Environmental Protection Agency [7]. An analysis of eight trace metals was done at the CESPT wastewater treatment plant at Punta Bandera, Tijuana.

A statistical analysis of the laboratory results including average values, total and seasonal variances, and standard deviation was done using E-Views software.

Equipment used included a Hach DR-4000 UV-VIS spectrophotometer, Finnigan CG Ultratrace coupled with an MS Finnigan Polaris Q with ion trap. Metal quantification was done with a Varian Ultramass 700 ICP-MS, using the US American Public Health Association's method 3000 (APHA 1999). A conventional microscope and a BBL Crystal system were used to identify helminth eggs and bacteria, respectively.

Most sampling was done weekly, with samples being taken on each of the seven days of the week.

4 Results

As can be seen in Table 1, the majority of the total dissolved solids was found to consist of chlorides and sulfates such as sodium salts. Also reflected in the overall level of water hardness were salts derived from calcium and magnesium, as well as carbonates and bicarbonates. These salts were not evaluated in this part of the project, but deserve consideration.

Table 1: Results of chemiophysical analysis.

Parameter	Minimum value	Maximum value	Average	Standard Deviation	Variance	Number of samples
pH	6.45	7.7	7.43	0.2696	0.072	36
Conductivity	1630	2240	2050.28	131.29	17238.15	35
Color	40	255	73.13	41.06	1686	36
Turbidity	<14	25	19.2	3.89	15.2	5*
TDS	1100	2115	1375.73	199.36	39744.5	34**
TSS	< 10	138	57.5	54.28	2947	4*
Total Hardness	110	1394	503.91	195.39	38180.02	36
Chloride	140	362	286.44	40.669	1653.968	36
Fluoride	0.09	2.2	1.22	0.517	0.268	35**
Phenols	< 0.001	0.006	0.0029	0.0016	2.59E-06	21*
Surfactants	0.03	1	0.198	0.19	0.036	35**
Total Chlorine	< 0.01	2.2	0.177	0.381	0.145	31*
Free Chlorine	< 0.02	1.6	0.131	0.303	0.091	26*
Cyanide	< 0.01	0.2	0.028	0.033	0.001	31*
Nitrate	0.01	3	0.446	0.708	0.502	36
Nitrite	< 0.001	2.5	0.202	0.441	0.194	33*
Ammonia	0.25	110.8	13.88	21.9	479.62	36
TKN	1.9	86.3	29.19	20.88	436.01	36
Orthophosphate	2.4	33.6	13.61	10.35	107.2	36
Total Phosphate	15.5	38.2	28.8	5.85	34.31	29**
Sulfates	197	1200	461.3	197.15	38869.7	36
Oil and Greases	< 5	270	63.38	67.69	4583.075	18*
BOD_5	< 5	41	16.5	16.46	271	4*
COD	30	363	69.75	55.44	3074.02	36

Note: *Samples falling below detectable levels are not included
**Number includes only samples that could be analyzed

The quantity of organic material was minimal with respect to DBO_5, and does not represent a problem for the reuse of treated wastewater.

The majority of the nitrogen present (TKN: 1.9-86.3 mg/L) was found to consist of proteins that remained as a result of the short retention time, as well as the poor oxygenation during the treatment process.

Table 2 reveals that the analyses of microbiological contaminants yielded positive results in only 33% of the cases. Table 3 shows that the tests for helminth eggs were all negative, with only one sample testing positive for uncinaria larvae.

None of the 16 samples analyzed for trace metals exceeded the limits established in Mexican government standard NOM-001-ECOL-1996 [8] for each of the eight metals mentioned in the standard.

As shown in table 5, only 11 of the 36 samples analyzed showed one or more of the 17 different volatile compounds detected.

Table 6 shows the comparison of parameters having the highest values or fluctuations with regard to the limits established in relevant Mexican federal standards for reservoirs and regional water supplies.

Table 2: Results of microbiological analysis.

Sample	Total Coliforms NMP/100ml	Fecal Coliforms NMP/100ml	Mold UFC/ml	Yeast UFC/ml	Enterococcus	Enterobacterias
09Nov06	Negative	Negative	Negative	Negative	Negative	Negative
22Nov06	Negative	Negative	Negative	Negative	Negative	Negative
17Jan07	Negative	Negative	Negative	Negative	Negative	Negative
08Feb07	Negative	Negative	Negative	Negative	Negative	Negative
28Feb07	Negative	Negative	Negative	Negative	Negative	Pseudomona Aeroginosa
06Mar07	Negative	Negative	Negative	Negative	Negative	Negative
14Mar07	Negative	Negative	Negative	Negative	Negative	Negative
22Mar07	Negative	Negative	Negative	Negative	Negative	Negative
10Apr07	Negative	Negative	Negative	Negative	Negative	Negative
10Apr07	Negative	Negative	Negative	Negative	Negative	Negative
14Apr07	Negative	Negative	Negative	Negative	Negative	Negative
22Apr07	3	3	2	1	Negative	E. coli
01Jun07	Negative	Negative	Negative	Negative	Negative	Negative
09Jun07	Negative	Negative	Negative	2	Negative	Negative
13Sep07	Negative	Negative	Negative	Negative	Negative	*Enterobacter cloacae*
20Sep07	Uncountable	Uncountable	Negative	Negative	*Enterococcus faecium*	Negative
21Sep07	Negative	Negative	Negative	Negative	Negative	*Enterobacter cloacae*
29Sep07	Negative	Negative	Negative	Negative	*Staphylococcus hominis*	Negative
07Oct07	30	Negative	Negative	Negative	Negative	Negative
15Oct07	15	Negative	Negative	Negative	Negative	Negative
30Oct07	Negative	Negative	Negative	Negative	Negative	*Enterobacter cloacae*

Table 3: Results of analysis of helminth eggs.

Number of Sample	Results
1	Negative
2	Negative
3	Negative
4	Negative
5	Negative
6	Negative
7	Negative
8	Negative
9	Uncinaria Larvae
10	Negative
11	Negative
12	Negative
13	Negative
14	Negative
15	Negative
16	Negative
17	Negative
18	Negative
19	Negative
20	Negative
21	Negative
22	Negative
23	Negative

Table 4: Results of analysis of metals.

Date	Analysis (mg/L)							
	Arsenic	Cadmium	Copper	Chromium	Mercuric	Nickel	Lead	Zinc
9Nov06	0.004	< LD	0.007	0.001	< LD	0.005	0.001	0.062
22Nov06	< LD	< LD	0.03	0.003	< LD	0.05	< LD	0.043
22Mar07	< LD	< LD	< LD	< LD	NA	< LD	< LD	0.087
30Mar07	< LD	< LD	< LD	< LD	NA	< LD	< LD	0.126
10Apr07	< LD	< LD	0.008	< LD	< LD	< LD	< LD	0.075
14Apr07	< LD	< LD	< LD	< LD	< LD	< LD	< LD	0.075
22Apr07	< LD	< LD	0.004	0.006	< LD	0.009	< LD	0.093
30Apr07	< LD	< LD	< LD	< LD	< LD	< LD	< LD	0.087
8/May07	< LD	< LD	< LD	< LD	< LD	< LD	< LD	0.084
16May07	< LD	< LD	< LD	< LD	< LD	< LD	0.003	0.095
24May07	< LD	< LD	< LD	< LD	< LD	< LD	< LD	0.076
1Jun07	< LD	< LD	< LD	< LD	< LD	< LD	< LD	0.063
9Jun07	< LD	< LD	< LD	< LD	< LD	< LD	< LD	0.057
29Sep07	< LD	< LD	< LD	< LD	< LD	0.006	0.001	< LD
31Oct07	< LD	< LD	0.007	0.02	< LD	0.005	0.003	0.094
24Nov07	< LD	< LD	< LD	0.004	< LD	< LD	0.001	0.067
NOM-001	0.1	0.1	4	0.5	0.005	2	0.2	10

Note: <LD = Less than detection limit.

Table 5: Results of analysis of organic compounds.

Parameter (ppm)	Sample										
	22Mar07	17Jun07	04Ago07	20Ago07	28Ago07	05Sep07	13Sep07	21Sep07	29Sep07	10Dec07	18Dec07
Chloromethane	453.6	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	527.95	353.71
Toluene	N.D.	N.D.	4.4	3.91	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Ethylbenzene	1.15	3.12	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,1,2,2 Tetrachloroethane	N.D.	N.D.	5.98	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,3 Dichlorobenzene	4.38	3.51	1.62	0.8	3.06	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,4 Dichlorobenzene	5	4.62	2.16	1.14	3.09	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,2 Dibromoethane	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,2 Diclorobenceno	N.D.	4.61	1.57	0.98	2.95	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Acetone	40	71.82	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	29.4	43.96
2-Hexanone	N.D.	N.D.	7.98	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
4-Methyl-2-pentanone	N.D.	N.D.	12.47	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,2,3-Trichlorobenzene	N.D.	N.D.	3.99	2.25	4.33	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Methyl methacrylate	N.D.	N.D.	3.13	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Styrene	N.D.	4.7	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
m-Xylene	N.D.	3.3	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
o-Xylene	N.D.	7.05	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Carbon disulfide	N.D.	1.9	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	21.22	132.02

Note: ND = Not Detected.

Table 6: Comparison of seasonal effluent quality.

Parameter	PTARRN Winter-Spring 2006-2007	PTARRN Spring -Summer 2007	PTARRN Fall-Winter 2007	NOM-127-SSA1 1994	NOM-001-ECOL 1996	Carrizo Dam	Rodri-guez Dam	Las Palmas Valley		
								Average	Mini-mum	Maxi-mum
Cyanide	0.0138	0.0245	0.02469	0.07	1	NR	NR	NR	NR	NR
Free Chloride	0.79	0.042	0.0715	0.2-1.5	NR	NR	NR	NR	NR	NR
Chloride	250.6	283.11	304.8461	250	NR	198	135	767.6	121	3537.9
Total Hardness	760.8	488.1667	426.923	500	NR	340	224	894.9	227.6	4034.1
Phenols	-0.001	0.001	0.0025	0.001	NR	NR	NR	NR	NR	NR
Fluoride	1.475	1.45	0.8353	1.5	NR	NR	NR	NR	NR	NR
Total Phosphorus	NR	29.935	27.5776	NR	5	NR	NR	NR	NR	NR
Nitrate	0.03	0.1255	1.0507	10	NR	NR	NR	NR	NR	NR
Nitrite	0.012	0.0578	0.4283	0.05	NR	NR	NR	NR	NR	NR
Ammonia	1.68	22.85	6.1669	0.5	NR	0.18	0.24	NR	NR	NR
TKN	21.18	41.879	14.7115	NR	15	NR	NR	NR	NR	NR
pH	7.486	7.43	7.42	6.5-8.5	5.0-10.0	NR	NR	NR	NR	NR
TDS	1469	1318.235	1415.4615	1000	NR	582	485	2030	470	7740
Sulfate	404.8	422.8829	536.2307	400	NR	608	81	274.2	43	783
Surfactants	0.2375	0.2061	0.1761	0.5	NR	NR	NR	NR	NR	NR

NR= Not Reported.

5 Conclusions

The majority of the effluent's constituents fall below both the maximum levels permitted by the relevant Mexican federal standards and the levels found in the region's major reservoirs. However, if direct reuse is desired, the State Commission of Public Services of Tijuana must plan some type of tertiary treatment.

If the effluent is to be used indirectly for recharging reservoirs by means of infiltration, an acute toxicity study should be done in order to determine the levels at which the effluent would represent a danger to organisms in the receiving body of water. Such a study should be done according to Mexican standard NMX-AA-087-1995-SCFI[9].

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