ASSESSMENT OF WASTEWATER FOR DISPOSAL IN ACCORDANCE WITH NEQS CRITERIA AND ITS REUSE FOR IRRIGATION WITH DILUTION

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ABSTRACT

According to Section 11 of Pakistan Environmental Protection Act (PEPA) 1997, "No person shall discharge or emit or allow the discharge of any effluent or waste in an amount, concentration or level which is more than the National Environmental Quality Standards(NEQS)". Even in the presence of this act there are many housing societies and Industrial zones, which are continuously disposing off their untreated wastewater to the natural water bodies. In this study Laboratory investigations on 5 composite samples were carried out. Total of 19 parameters were analyzed including Total Dissolve Solid (TDS), Total Suspended Solids (TSS), Bio-Chemical Oxygen Demand (BOD), Chemical Oxygen demand (COD), Sulfide, Fluoride, Lead, Nickel, Boron, Copper, Iron, Zinc, Manganese, Chlorine Total and Chromium hexavalent with average value of 502.6, 665.6, 267.4, 453.8, 3.1,5.3 0.6, 0.4, 1.4, 0.5, 0.5, 2.15, 0.6 and 0.5 mg/L respectively. TSS, BOD, COD and Mn exceeded the limits of NEQS for all samples.

The same wastewater can be used for irrigation purpose if it fulfills FAO irrigation water criteria. For this purpose, important properties like SAR, Sodium ratio, Salt Index, Residual Sodium Carbonate, Permeability Index, Magnesium Adsorption Ratio, Sulfate ion and Boron were analyzed having result of 9.36 √(meq/L), 5.64, 75 ppm, 4.66 meq/L, 110.46, 0.42, 6.07 meq/L, 1.386 mg/L mean concentrations respectively, violating the standards. A dilution factor of 1.09 litters is computed per liter of sewage to minimize, the concentrations of exceeded parameters by mixing with normal water, into a range that can be used safely for irrigation.

KEY WORDS: wastewater analysis, NEQS, water criteria, FAO water criteria, Dilution factor

INTRODUCTION

Wastewater is any water after use and can originate from many sources such as; homes, businesses, industries. parking lots, streets and agriculture lands etc. The source will determine its characteristics, degree of impurities and how to be treated. For example, wastewater from homes and businesses (domestic sewage) typically contains pollutants such as; fecal and vegetable matter, grease and scum, detergents, rags and sediment. On the other hand, wastewater from an industrial process (industrial sewage) may include; toxic chemicals, metals, very strong organic wastes, radioactive wastes, large amounts of sediment, high temperature etc.

According to the Pakistan Environmental Protection Act (PEPA-97)[1], all the industries, housing societies and any other discharging wastewater sources must have a proper check and balance, as well as treating facility to bring down concentration of impurities within the limits of NEQS[2]. Otherwise they will get the penalties stated by the same act. Unfortunately, besides having Environmental Protection Agency (EPA)[3] violation of the mention act is a common phenomenon. An attempt is made in this study to analyze wastewater of the selected housing society and treat it to fit for irrigation purpose.

Developing countries like Pakistan are disposing great amount of domestic and industrial wastewater into streams and rivers without proper treatment. Water quality of natural rivers and streams are becoming inferior due to mixing of large quantity of untreated wastewater. In 2002, wastewater samples for 10 different industries in Hayatabad Industrial Estate were analyzed. A number of chemicals were found above NEQS levels[4]. In 2011 the Ravi River water characteristics was investigated and found that the impurity level is four times more than NEQS[5]. It is necessary to analyze and formulate such strategies for water quality management which would maintain acceptable water quality standards for disposal.

Different methods of wastewater treatments including

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physical, chemical and biological treatment are being used in different countries all over the world. But all the treatment processes require huge investment and large areas to operate commercially. So, for a country like Pakistan low cost processes like oxidation ponds and dilution remains only choices. The prior requires sufficient area, skilled labors and maintenance to operate.

Wastewater is extensively used in agriculture because it is a rich source of nutrients; reducing the need for chemical fertilizers and hence net cost savings to the farmers. Wastewater suitability for irrigation should be based on FAO guidelines[6,7].

Wastewater irrigation have both positive as well as negative effects like it provide sufficient nutrients, preventing water to be wasted, saving natural water bodies and aquatic life to be effected, overcome water shortage problems and bring more area under cultivation. While the negative effects are high risk to human health through food chain, toxic metal accumulation on surface, salinity problems, ground water contamination, killing microorganisms in soil[8]. However, these problems are associated with the continuous use of wastewater for irrigation as indicated by a study conducted in Mexico[9]. In Cario region, untreated water has been used for irrigation since 1915[10,11].

Irrigation with diluted wastewater

The use of urban diluted wastewater for irrigation in agriculture is centuries old practice that has received renewed attention due to increasing scarcity of freshwater resources in many arid and semi-arid regions. Irrigation with raw or diluted wastewater is a widespread phenomenon, occurring on 20 million hectares across the developing world, especially in Asian countries[12].

Dilution is the mixing of wastewater with normal water in a ration called dilution factor, which will not eliminate the impurities but bring their concentrations to a level which will not affect land and crops. This practice is not limited to the developing world but also used by many nations around the globe like Spain, Italy, China, Brazil, and some countries of the Middle East and North Africa region[13].

METERAILS AND METHODS

Sampling

The value of any laboratory result depends on the integrity of the sample. The objective of sampling is to collect a portion of wastewater small enough in volume to be conveniently handled in the laboratory and still enough to be the representative of wastewater to be examined. Two types of sampling were used depending on the parameter to be tested, that is grab sampling consists of a single sample taken at a specific time required for pH, Temperature, Ammonia etc. while on the other hand composite sampling consists of a mixture of several individual grab samples collected at regular and specified time periods, each sample taken in a constant

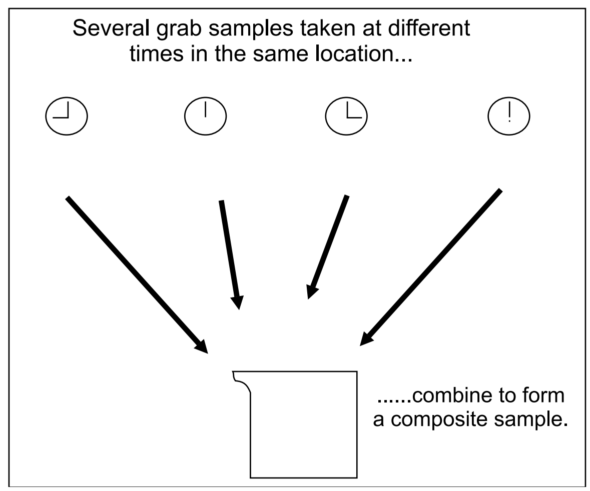

Figure1: Composite sampling

proportion as shown in Figure-1. This type of sampling was used for the rest of parameters.

Sampling points

The samples were taken where the wastewater was well mixed; large particles were excluded and were readily accessible. The selected locations for sampling are shown in Figure-2.

P1: At the exit of wastewater treatment plant (currently nonfunctional) at phase III chowk.

P2: A point 500 meters upstream the same treatment plant

P3: A location 500 meters downstream the same treatment plant

P4: At the end of North Nalla before joining the main stream near to Marcopolo hotel

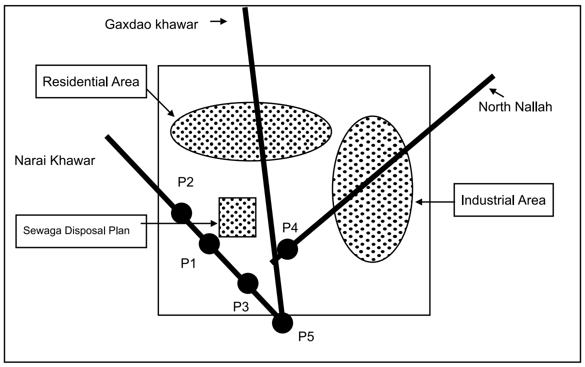

Figure 2: Sample points location

P5 : is Downstream the Board bazaar at canal Town Bridge.

Analysis of collected samples

The collected water sample were analyzed for the parameters shown in Table 1. Every parameter has separate method of analysis like some were found by using an electronic instrument while the other required titration. The method used for analysis of each parameter is shown in Table 1.

The results obtained from the 5 samples were compared with NEQS criteria for disposal to the natural water body.

Assessment of Wastewater for Irrigation Purposes

The following criteria were used to evaluate the quality of wastewater and its suitability for irrigation.

- Salinity hazard
- Sodium hazard
- Salt index
- Alkalinity hazard

Table 1: Parameter with Method of findings

S.No	Parameter	unit	Method
1	pH		pH-meter
2	Electrical conductivity	dS/m	EC-meter
3	Total dissolve solids	g/L	EC-meter
6	BOD	mg/L	Dilution
7	COD		ISO 6060
8	Bicarbonates (HCO3--)		Titration
9	Carbonates (CO3-)		Titration
10	Ammonia		Paqualab photometer
11	Nitrate (NO3)		Paqualab photometer
12	Sulfate SO4-		Paqualab photometer
13	Nitrogen Ammonia		Spectrophotometer
14	Chromium hexavalent		Spectrophotometer
15	Phosphate		Spectrophotometer
16	Chloride		Spectrophotometer
17	Fluoride (as F)		Spectrophotometer
18	Chlorine total		Spectrophotometer
19	Sodium (Na)		Flame photometer

Continued on next page

20	Potassium (K)		Paqualab photometer
21	Calcium		Atomic absorption sp
22	Magnesium		Atomic absorption sp
23	Lead (Pb)		Paqualab photometer
24	Nickel (Ni)		Paqualab photometer
25	Boron	mg/L	Paqualab photometer
26	Aluminum		Paqualab photometer
27	Copper		Paqualab photometer
28	Iron		Paqualab photometer
29	Zinc		Paqualab photometer
30	Manganese		Paqualab photometer

- Permeability hazard
- Specific ion toxicity hazards

Each of the above parameter was computed for each sample and then compared with the limit defined by FAO in next chapter.

Dilution Factor for analyzed sample

After the assessment of wastewater for irrigation purpose, the amount of tape water required per unit volume of wastewater is computed in order to make the water suitable for irrigation. First, those parameters which were exceeding the standards(NEQS) were pointed out. Then in normal water the concentration of the same parameters was determined in the laboratory. Then according to the law of conservation of mass the fallowing equation was used with the fallowing assumptions

- The chemicals parameters are treated as conservative
- The amount of concentration remains constant for each of two mixing partners
- The flow is conserve that is no addition and no extraction occurs.

Mathematically

$$Q_s\, C_s = C_w\, Q_w + C_T\, Q_T \qquad (1)$$

where,

$Q_s =$ Volume of standard solution (L)

$C_s =$ Concentration of standard solution (mg/L)

$Q_w =$ Volume of wastewater (L)

$C_w =$ Concentration of wastewater (mg/L)

$Q_T =$ Volume of tap water (L)

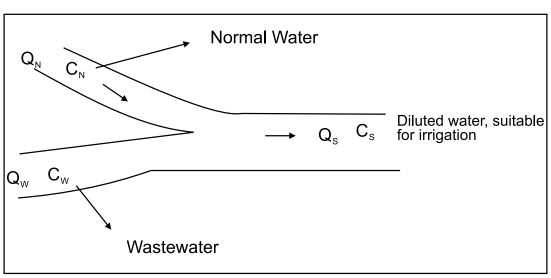

Figure 3: Schematic diagram for dilution of wastewater

$C_T =$ Concentration of tap water (mg/L)

$$Q_T = (C_w - C_s) / (C_s - C_T) \; \ldots\ldots\ldots \; (2)$$

For $Q_w = 1$ liter

RESULTS AND DISCUSSION

Comparison with NEQS Criteria for Disposal

Total 19 parameters were analyzed for NEQS criteria. 8 out of 19 parameters are exceeding the standard values either completely for all samples or for some of the samples. The remaining 11 were in the range of NEQS. The exceeding elements are dangerous for aquatic environment, agricultural land use and human health. The data is shown in Table 2.

The Total Suspended Solids (TSS) values range from 50 to 2300 mg/L. The comparison shows that sample S3 and S5 are within the range. The remaining three samples S1, S2 and S4 with values of 2300, 601 and 253 respectively are exceeding the NEQS values. Sample S5 is 1533% more than the standard.

The values for BOD range from 123 to 640 mg/L. All the samples are above in the limit. With such a level of BOD, the disposal of wastewater is a great cause of oxygen deficiency in the receiving water bodies threatening the aquatic life to the receiver. The results are graphically shown in Fig.5.

The COD values ranges from 252 to 968 mg/L. All the samples are above the limit 50 mg/L. With such a great violation, it will disturb the ecosystem of receiving water bodies. The results are graphically shown in Figure 6.

The manganese values range from 1.7 to 2.5 mg/L. The results of all the samples are above the standard which is 1.5 mg/L. The difference between the normal and measured concentration is quit high and hence this will negatively affect the water quality of receiving body especially causing the problem of odor and taste. The results are graphically shown in Fig.7.

Zinc, Iron, Boron, Nickel, Fluoride, Chromium hexavalent, nitrogen ammonia, sulfate and total dissolve solid are all with the standard range of NEQS for all

Table 2: Comparison of computed parameters with NEQS criteria.

S.No	Parameter	Unit	S1	S2	S3	S4	S5	NEQS
1	TDS	g/L	770	610	335	532	266	3500
3	TSS		2300	601	124	253	50	150
4	BOD		640	272	141	152	132	80
5	COD		968	492	252	295	262	150
6	Sulfide		0.46	0.9	1	9	4	1
7	SO4-		316	188	231	566	156	600
8	Ammonia		10.1	26	33.3	45	9.8	40
9	Cr6		0.6	0.5	0.35	0.8	0.3	1
10	Mn		2.5	1.9	1.8	1.7	1.95	1.5
11	Chloride	mg/L	31	48	79.9	103	44	1000
12	Fluoride		4.6	5.5	7.5	6.7	2.4	20
13	Chlorine		1.77	0.9	0.15	0.3	0.2	1
14	Lead (Pb)		0.26	0.7	0.39	1.2	0.2	0.5
15	Nickel		0.13	0.4	0.41	0.2	0.7	1
16	Boron (B)		1.76	2.3	0.7	2	0.1	6
17	Cu		1.13	0.2	0.32	0.7	0.2	1
18	Iron (Fe)		0.38	0.9	0.32	0.5	0.2	2
19	Zinc (Zn)		0.17	1.7	0.2	0.3	0.1	5

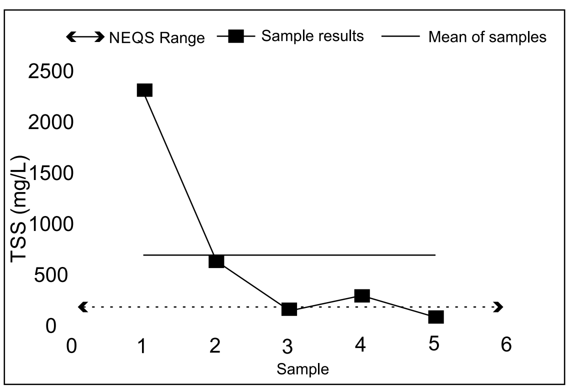

Figure 4: Total suspended solids of samples Vs NEQS range

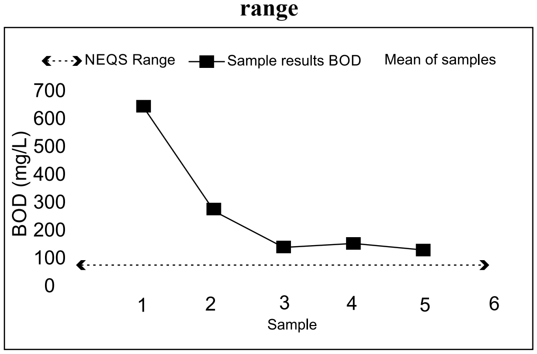

Figure 5: Samples results for BOD Vs NEQS range

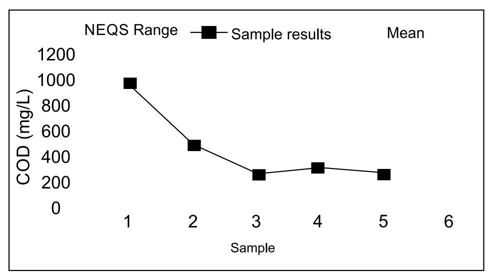

Figure 6: Samples results for COD Vs NEQS range

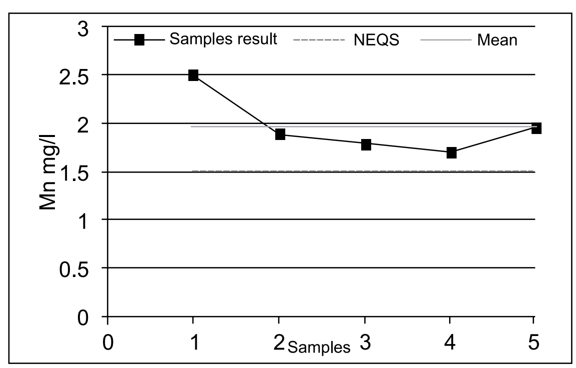

Figure 7: Samples results for Manganese Vs NEQS range

the samples. The copper and chlorine total violates for only for sample S1, while all other samples fall within range of NEQS. Lead and sulfide are above the NEQS range for two samples (S2, S4) and (S4, S5) respectively,

Table 3: Parameters competed for irrigation water quality

S.No	Parameters	Unit	Sample # 01	Sample # 02	Sample # 03	Sample # 04	Sample # 05
1	SAR	√(meq/L)	13.74	10.09	7.07	10.3	5.59
2	RSBC	meq/L	7.65	2.79	4.78	7.02	2.62
3	RSC	meq/L	6.93	1.93	4.47	6.63	3.32
4	RSC/RSBC	..	0.91	0.69	0.93	0.94	1.26
5	Permeability index	..	113.19	104.81	119.9	110.24	104.17
6	Sodium Ration	..	8.65	6.15	4.76	5.53	3.1
7	Magnesium ratio	..	0.57	0.64	0.28	0.23	0.4

while remaining three samples lies within range.

Assessment for irrigation water quality

The parameters were computed in order to check the suitability for irrigation shown in Table3.

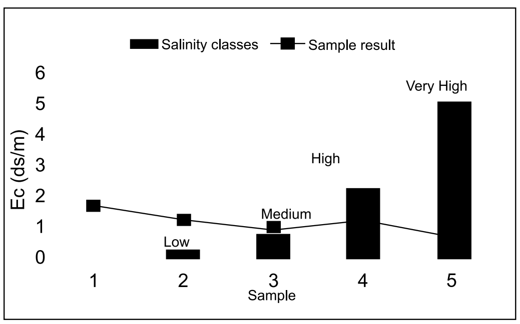

Figure 8: Graphical representation of Salinity classes

Salinity hazard was evaluated by using electrical conductivity at 25°C[14,15]. One sample (S5) lies in medium salinity water class which can be used with moderate leaching. The remaining four samples lies in high salinity

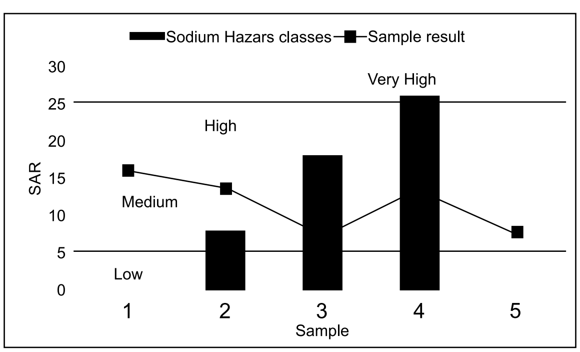

Figure 9: SAR values vs Sodium hazards classes

water classes which can be used for irrigation with some management practices. The mean value is 1.17 which lies in high water salinity class as shown in Fig.8.

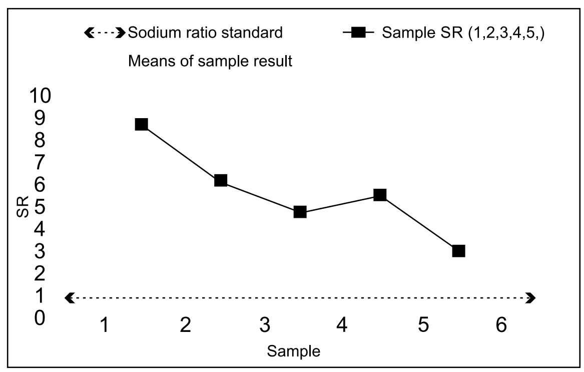

Figure 10: SR for Samples Vs Standard value

The SAR is calculated using the concentration of Sodium, Magnesium and Calcium in meq/L. Generally, water with Sodium Absorption Ratio (SAR) greater than 9 can cause severe permeability problems when applied to fine-textured (clay) soils continuously. Only two samples were in the range.

The Sodium Ratio (SR) for all samples were above with a great margin from standard value which is indicating that it will present a high sodium hazard for soil and crop if used for irrigation.

The salt index is used for predicting sodium hazard.

Salt index = (Total Na – 24.5) - (Total Ca-Ca in CaCO3) x 4.85

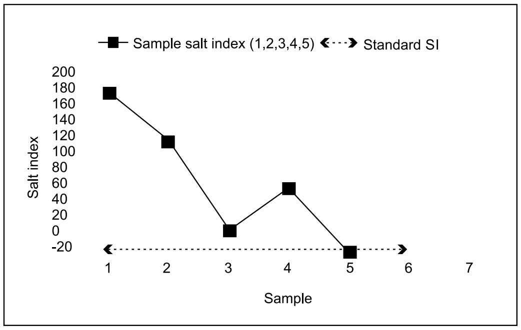

Figure 11: Salt index graphical representation

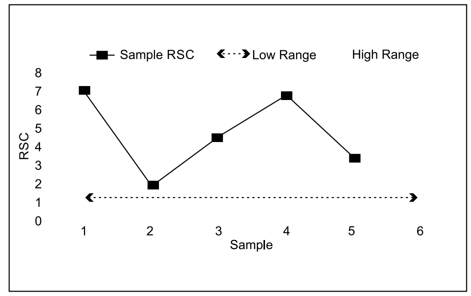

Figure 12: RSC of samples Vs Standard values

Where all ions expressed in ppm, Salt index is negative for all good water and positive for those unsuitable for irrigation. For four samples, the results were positive and hence not suitable for irrigation only one sample lies in range as shown in Fig.11.

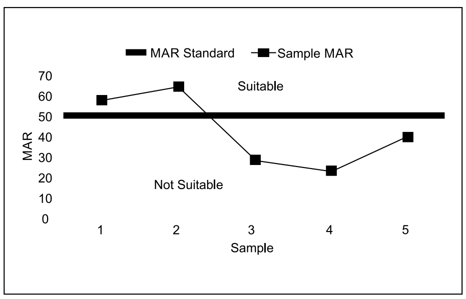

Figure 13: sample MAR vs Standard

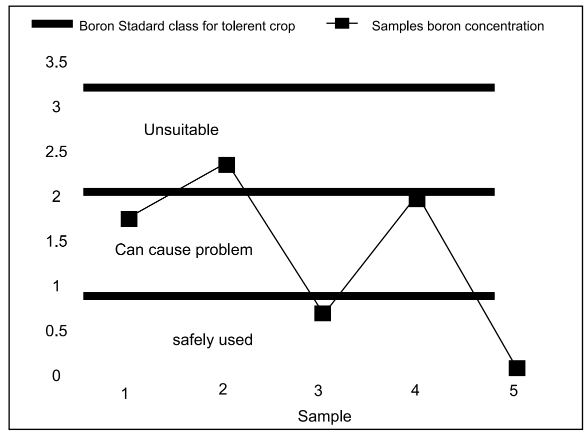

Figure 14: Born concentration Vs standard

Table 4: Calculation for dilution factor

S. No	Parameter	Unit	Mean	proposed range (tolerant crop)	normal water	normal water required (L)
1	Nitrogen	mg/L	24.980	22.600	0.001	0.105
2	Nitrate		70.756	50.000	3.600	0.447
3	Sodium		206.84	85.000	3.500	1.495
4	Boron		1.386	1.250	0.025	0.111
5	Aluminum		5.240	5.000	2.000	0.080
6	Chromium		0.508	0.250	0.002	1.040
7	Fluoride		5.000	2.000	0.001	1.501
8	Lead (Pb)		0.566	0.250	0.001	1.269
9	Manganese		1.500	0.400	0.001	2.757
10	copper		0.484	0.200	0.002	1.434
11	Nickel		0.361	0.200	0.010	0.847
12	HCO3-		354	125	10	1.991
mean value of tape water required				1.09		

Alkalinity hazard was determined by Residual Sodium carbonate (RSC). Its values for 4 out of five samples lies in the high alkalinity range and cause severe problem on application.

Special Ion Toxicity

High Mg adsorption by soils affects their physical properties. Its values for 3 out of five samples were in unsuitable range and will produce problems like hardness when used for irrigation as shown in Fig.13.

The occurrence of boron in toxic concentration in wastewater makes it necessary to consider this element in assessing the water quality. The boron value when exceeding 1 will create problems. Only two samples lie in safe range, the remaining were above the range. The results are shown in Fig.14.

Various nutrients necessary for crop growth like NO_3, K, N, Ca and Mg are present with mean values of 70.8, 12.4, 25, 16.6 and 7.1 mg/L respectively, which show that wastewater, has the potential to be used for irrigation. It can provide sufficient help in fulfilling the crop requirement for nutrients**.**

Dilution factor Calculation

For calculation of dilution factor, first the concentration for the exceeding elements were found out in normal water and then from the equation discussed in previous section. The amount of normal water required per liter of waste was calculated. The mean values of the out-range parameters were used for calculation as shown in Table 4.

Using equation discussed in previous section and then taking average, the dilution factor computed was 1.09 liters.

CONCLUSION

Out of 19 parameters 8 violates the NEQS criteria including BOD, COD, TSS and Mn etc. This indicates Severe threats to contamination of water bodies, reduction in fertility of agriculture land, pollution of downstream water bodies and aquatic life disturbance.

parameters like SAR, Sodium Ratio, Salt Index, Residual Sodium Carbonate, Permeability Index, Magnesium Adsorption Ratio, Sulfate ion and Boron with mean values 9.36, 5.64, 75 ppm, 4.66 meq/L, 110.46, 0.42, 6.07 meq/L and 1.386 mg/L respectively above the limits of FAO irrigation water quality guidelines and hence, can produce different problems to crops and soil. Some of the trace elements like Mn, Cu and other ions like fluoride also cross the standards for all the samples

On the other hand, various nutrients necessary for crop growth like NO_3, K, N, Ca and Mg are present with mean values of 70.8, 12.4, 25, 16.6 and 7.1 mg/L respectively, which show that wastewater, has the potential to be used for irrigation. It can provide sufficient help in fulfilling the crop requirement for nutrients.

The Dilution factor calculation shows that only 1.09 Liters of normal water are required to obtain the benefits of wastewater for irrigation.

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