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Effect of Urban Wastewater on the Quality of Ground Water in Mysuru City, India

[1]Abhilash M R, [2]Shiva Kumar D* and [3]Srikantaswamy S

Department of Studies in Environmental Science,
University of Mysore, Manasagangothri, Mysuru-570 006, India.

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ABSTRACT

The Mysuru is a unique city and was the capital city of former princely state of Karnataka, and its groundwater resources are developed for water supply and irrigation purposes. In order to evaluate the quality of groundwater in study area, 07 groundwater samples were collected and analyzed for various Secondary parameters. Including Physical and chemical parameters of groundwater such as Sodium Absorption Ratio, Residual Sodium Carbonate, Permeability Index, Corrosivity Ratio, Indices of Base exchange, $CaCO_3$ Saturation Indices, Gibb's plot of determining the Mechanisms controlling ground water Chemistry, Handa's Classifications, USSL Clasifications , $CaCO_3$ Saturation Indices and Stuyzfzand's were determined and the indices were calculated. Based on the analytical results, groundwater in the area is generally fresh and hard to very hard. The abundance of the major ions is as follows: HCO_3 > SO_4 > Cl and Ca > Mg > Na > K. The dominant hydrochemical facieses of groundwater is Ca-HCO_3 and Ca-Mg-HCO_3 type. The results of calculation saturation index by basic computer program HYCY shows that the nearly all of the water samples were saturated to under saturated with respect to carbonate minerals and under saturated with respect to sulfate minerals. Assessment of water samples from various methods indicated that groundwater in study area is chemically not suitable for drinking and agricultural uses.

Key words: Mysuru, Karnataka, Ground Water, Hydrochemical Facies,

I INTRODUCTION

Considerate the aquifer hydraulic properties and hydrochemical characteristics of water is crucial for groundwater planning and management in the study area. Normally, the motion of groundwater along its flow paths below the ground surface increases the concentration of the chemical species [1–3]. Hence, the groundwater chemistry could reveal important information on the geological history of the aquifers and the suitability of groundwater for domestic, industrial and agricultural purposes. Moreover, pumping tests with the drilling results are the most important information available for the groundwater investigations, as they are the only methods that provide information on the hydraulic behavior of wells and reservoir boundaries [4-5]. Hydrochemical evaluation of groundwater systems is usually based on the availability of a large amount of information concerning groundwater chemistry [6-7]. Quality of groundwater is equally important to its quantity owing to the suitability of water for various purposes [8-9]. Groundwater chemistry, in turn, depends on a number of factors, such as general geology, degree of chemical weathering of the various rock types, quality of recharge water and inputs from sources other than water and rock interaction. Such factors and their interactions result in a complex groundwater quality [1-10-11]. The rapid increase in the population of the country has led to large scale groundwater developments in some areas. Intense agricultural and urban development has caused a high demand on groundwater resources in arid and semi-arid regions of Iran while putting these resources at greater risk to contamination [12–14]. Groundwater is an important water resource for drinking, agriculture and industrial uses in study area. In this study, physical, hydrogeologic, and hydrochemical data from the groundwater system will be integrated and used to determine the main factors and mechanisms controlling the chemistry of groundwater in the area. The relationship between groundwater flow, hydrogeologic properties and hydrochemistry has been studied by many researchers [2-15-16]. The chemical quality of groundwater is related to the lithology of the area. The topography of the city is such that the entire Urban wastewater drains into three valleys viz., northern out-fall into Kesare Valley, and other outfalls to the south one into Dalvai tank feeder valley and another to Malalavadi tank valley. Based on the topography of the city, Mysuru city comprises of five drainage districts, namely, A, B, C, D and E districts respectively, covering different areas. The city has been provided with three wastewater treatment plants. Drainage districts of A & D have the wastewater treatment plant of capacity 60.00 MLD, which is located at Rayankere, H.D.Kote Road, Mysuru. The treatment plant for drainage district B is of capacity 67.65 MLD, which is located at sewage Farm, Vidyaranyapuram, Mysuru. The treatment plant for drainage district C is of capacity 30.0MLD, which is located at Kesare Village, Mysuru. City serves as a growth centre with intent to release the stress on the bangaluru metropolitan city. The following sampling stations were selected for the present study located at wastewater run-off and Wastewater irrigated areas of Semi-urban regions of Mysuru city.

II. Materials and Techniques Employed:

Best quality available, commercial analytical grade reagents and chemicals were used as such while preparing desired concentration and grades as per the "standard Method for Examination of water and wastewater" [23], and "Methods For Chemical Analysis of Water and Waste" by Environmental Protection Agency (EPA), 1983, those described by the central pollution control board (CPCB) in "Guide Manual: Water and Wastewater Analysis". The major ion concentration data has been processed using the HYCY- Basic Computer program developed [24]. In the program, hydrochemical facies classification is attempted using the criteria of [18-19-40-41-26]. The water types of this area have been identified using this procedure [28], proposed the corrosive tendencies of flowing water in a metallic pipe. Corrosivity ratio was calculated using the formula [27], proposed plots using the chloroalkaline indices for inferring the mechanism controlling the chemistry of groundwater. Sodium adsorption ratio (SAR) was calculated using the formula, The output of HYCY-Basic Computer program contains information pertaining to the ionic strength, Index of Base Exchange (IBE), Non Carbonate Hardness (NCH), total hardness water types of Stuyfund, Permeability Index of Donnen, Piper Hydrochemical Facies, USSL classes of water quality and the mechanism controlling water chemistry. A comprehensive picture of the water quality criterion is obtained using this software.

Figure 01: Sampling area Map

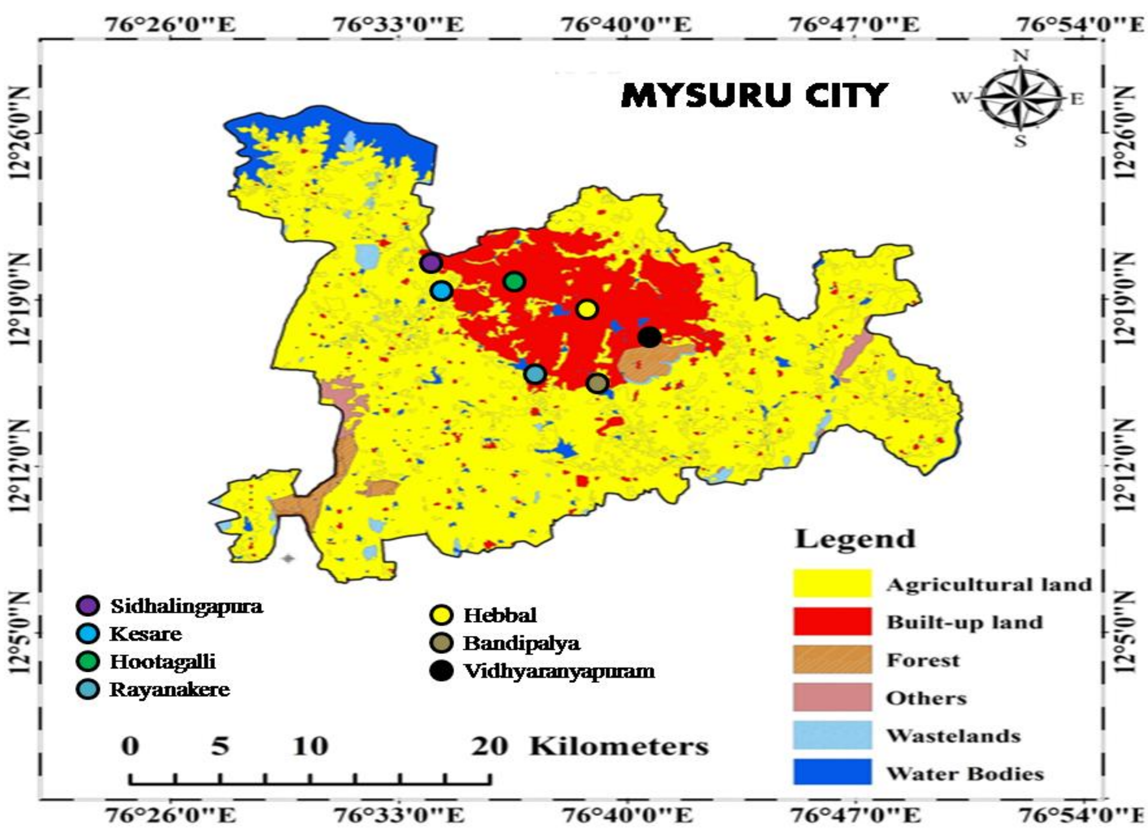

Table 01: Sample locations and Sample code.

Sample Code	Location
MYS-01	Kesare
MYS -02	Vidhyaranyapuram
MYS -03	Rayanakere
MYS -04	Hebbal
MYS -05	Bandipalya
MYS -06	Hootagali
MYS -07	Sidhalingapura

III Results and Discussions

Hydrogeochemical Studies: The soil zone has unique and powerful capacities to alter the water chemistry, as infiltration occurs through areas, the soil zone undergo a net loss of mineral matter to flowing water. As groundwater moves along flow lines from recharge to discharge areas, its chemistry is altered by the effect of variety of geochemical processes [29] in the present study also enlighten the Ground Water Facies: [33, 34, 36] and [36] introduced the concept of Hydrochemical facies [37]. The facies represent district zones with definite cation and anion concentrations and it depicts the diagnostic chemical character of water in various parts of the system. Flow patterns modify the hydrochemical facies and control their distribution. Hydrochemical facies of groundwater for the study region have been analyzed using the following approaches.

1. Sodium Absorption Ratio
2. Residual Sodium Carbonate
3. Permeability Index
4. Corrosivity Ratio
5. Indices of Base exchange
6. $CaCO_3$ Saturation Indices
7. Gibb's plot of determining the Mechanisms controlling ground water Chemistry
8. Handa's Classifications
9. USSL Clasifications
10. $CaCO_3$ Saturation Indices.
11. Stuyzfzand's Classification

Sodium Adsorption Ratio (SAR): The expression of the equilibrium between exchangeable positive ions (Cations) in the soil and cations in the irrigation water is known as Sodium Adsorption. It gives a measure of suiltability of water for irrigation with respect to the sodium (alkali) hazards High SAR values may cause damage to soil. The SAR may be determined by the formula (epm).

Sodium Adsorption Ratio	Water types
<10	Excellent
10-18	Good
18-26	Fair
>26	Poor

Table 02: Sodium Adsorption Ratio

From the experimental results obtained, it was found that, all the samples from the study area have found to be excellent type with respect to SAR values. MYS-01 found to have maximum epm of 9.915 and MYS-06 was minimum SAR among all the analyzed samples.

Residual sodium carbonate (RSC): In addition to the SAR and Na%, the excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium also influence the inappropriateness of groundwater for irrigation. This is termed as residual sodium carbonate (RSC) [46], Majority of irrigation water in India are affected with sodium hazards and contain Residual Sodium Carbonate (RSC) more than 2.5 me l-1 . The soils of this region are sandy loam to loamy sand in texture and having alkaline reaction. Continuous use of such sodic water develops high ESP and pH and low HC, which would result adverse effect on plant and soil. Present study MYS-04 was recorded maximum of 2.514 and MYS-07 recorded minimum value of -1279.

Permeability Index: Permeability data is often used in studies of groundwater and in particular during investigations of pollution or aquifer contamination. The soil permeability is influenced by long term used of irrigation water containing and Bicarbonates. Permeability Index is calculated using the formula [31] MYS—04 recorded maximum of 93.856 and MYS-03 recorded minimum value 67.801.

Corrossivity Ratio: Corrosion is an electrolytic process that takes place on the surface of the metals, which severely attacks and corrodes away the metal surfaces. Most of the corrosion problems are associated with salinity and encrustation associated with alkalinity [30] used the corrossivity ratio to evaluate the corrosive tendencies of river waters. Water having corrosivity ratio less than 1 is considered to be non- corrosive, while the value above 1 is considered as corrosive. From the analysis of all ground water samples, the corrosivity ratio was found to be greater than 1 epm, except, samples from MYS-04, which were found to have values less than 1 epm. MYS-01 sample found to have very high corrosivity ratio of 4.399 epm. The results indicate that, 92 % of the samples from the study area found to have corrosivity ratio greater than 1 epm.

Indices of Base Exchange: IBE [16-38-39] suggested two chloroalkaline indices CAI 1 and CAI 2 to indicate the exchange of ions between the groundwater and its host environment. The exchange of ions Na^+ and K^+ from the water with the Mg^{++} and Ca^{++} in the rock is designated as direct exchange. If the exchange is reversing, it is known as reverse exchange, this may be represented as a reversible chemical reaction. Based on Schoellers water type classifications, all the samples are falling under Type II except sample MYS-03 where it is fall under Type IV.

Calcium Carbonate Saturation Indices: The percolating water is assumed to equilibrate rapidly with soil carbon dioxide and calcite in an open system [17] becomes weakly acidic as a powerful weathering cum-dissolution agent and disintegrate, decompose the country rocks and leach away the soluble salt, while passing through calcium bearing rocks. Calcium is dissolved as $Ca(HCO_3)_2$ due to the influence of carbon dioxide, temperature, pH, Ionic strength of solutions and the organic content of groundwater.

Groundwater passes through unsaturated, saturated and over saturated stages of $CaCO^3$ saturation indices of groundwater for the present study area are calculated using,

1. The equilibrium pH method [15-18-19]
2. The equlibrium Ca^{++} method [42-43-44-30]

Mechanism of controlling groundwater chemistry: Gibb's (1970) discussed the relationship between water composition and aquifers lithology. Many of the researchers have studies the mechanisms controlling the groundwater composition of Karnataka. Gibb's plots distinguish the interaction of groundwater due to precipitation or rock interaction or evaporation by demarcating these folds. This helps in understanding the factors that control the chemistry of groundwater. According to Gibb's plot, all the samples in the study area are under the category of Rock interaction, except the sample MYS-02 are found to have the category of Evaporation.

Table 03: Gibb's plots

Category		No. of samples
Evaporation	Longer residence time	02
Rock Interaction	Dissolution mixing of mineral matter	12
Precipitation	Recent recharge water	00

Table 04: Basic Criteria used in Handa's Classification

Type	$Ca^{2+}+Mg^{2+}$	$Ca^{2+}+Mg^{2+}$	$Cl^{-}+SO_4^{2-}$	Charecterstics
A1	$>HCO_3^-$	$>Na^+K^+ +$	$<HCO_3^-$	Non-Carbonate Hardness
A2	$>HCO_3^-$	$>Na^+K^+ +$	$>HCO_3^-$	Non-Carbonate Hardness
A3	$>HCO_3^-$	$<Na^+K^+ +$	$>HCO_3^-$	Non-Carbonate Hardness
B1	$<HCO_3^-$	$>Na^+K^+ +$	$<HCO_3^-$	Carbonate Hardness
B2	$<HCO_3^-$	$<Na^+K^+ +$	$<HCO_3^-$	Carbonate Hardness
B3	$<HCO_3^-$	$>Na^+K^+ +$	$>HCO_3^-$	Carbonate Hardness

Table 05: Salinity TSC/TSA (epm)

C1	Low	<2.5
C2	Low to medium	2.5-7.5
C3	Medium to high	7.5-22.5
C4	High to very high	22.5-37.5
C5	Extremely high	>37.5

Table 06: Sodium Hazard

S1	Low sodium water	0-30
S2	Low to medium sodium water	30-57.5
S3	Medium to high sodium water	57.5-100

The study area characterized by both water having temporary and permanent hardness. But 64% of the water samples are in permanent hardness (A1, A2 and A3) remaining samples are in temporary hardness (B1, B2 and B3).

USSL Classification: According to a method formulated by the US Salinity Laboratory (1954), water used for irrigation can be rated based on salinity hazards and sodium or alkali hazards and sodium or alkali hazard. When the sodium hazard ratio and Electrical conductivity of water are known, classification of water for irrigation can be done by plotting these on the diagram. Low salinity water ($C1^-$ <250i-250mho/cm) can be used for irrigation of most crops on most soils with little likelihood that soil salinity will develop.

Table 07: USSL Diagram

Salinity Hazard	Sodium Hazard
S1 - Low	C1 - Low
S2 - Medium	C2 - Medium
S3 - High	C3 - High
S4 - Very High	C4 - Very High
S5 - Extreamly High	C5 - Extremely High

From the study, it was observed that, most of the samples from the study area are found to be C3S2, C4S2, and C2S1 type. Samples from all the samplese are found to have Medium Salinity with High Sodium hazard (C3S2) and MYS-03, are found to have Very high salinity with Medium sodium (C4S2)

Stuyfzand Classification: [39-40] proposed a hydrochemical classification system for the determination of water type that helps in successive identification of main types, such types and class of water sample.

Main types: The Chloride content determines the main types, as indicated in Table. The boundaries are based upon criteria discussed in [40]

Table 08: Division of main types based on Chloride concentrations.

Main Type	Code	Cl^- (mg/L)
Very Oligohaline	G	<5
Oligohaline	g	5-30
Fresh	F	30-150
Fresh brackish	f	150-300
Brackish	B	$300\text{-}10^3$
Brackish salt	b	$10^{3}\text{-}10^4$
Salt	S	$10^4 – 2.\,10^4$
Hyperhaline	H	$>2.\,10^4$

Boundaries in mg/L: 5, 30, 150, 300, 1000, 10000, 20000

From this classification, 03 water samples are characterized by Fresh. 03 Fresh Brackish and 01Brackish characterized. No samples sample found characterized by Oigohaline.

Types: Each main type is further subdivided into a maximum of 11 types according to alkalinity, Table The upper boundary of each type except no. 9, is defined by: Upper boundary type X= 2^x in meq/L**.** Where X is an integer between -1 and 9.

Table 09: Hydrochemical Parameter Characteristic of Ground water sample of Mysuru

Secondary Parameters	Kesare (MYS-01)	Vidhyaranyapuram (MYS-02)	Rayanakere (MYS-03)	Hebbal (MYS-04)	Bandipalya (MYS-05)	Hootagali (MYS-06)	Sidhalingapura (MYS-7)
Sodium Adsorption Ratio (SAR)	9.915	7.686	6.042	7.350	6.242	4.658	6.207
Residual Sodium Carbonate (RSC)	-5.056	-6.590	-3.915	2.514	-1.539	3.160	-1.232
Permeability Index(Doneen)	70.664	73.982	67.801	93.856	71.606	90.700	75.124
Corrosivity Ratio (CR)	4.399	1.361	2.314	1.010	1.601	1.239	1.279
Indices of Base Exchange (IBE)	-2.530 -0.541	-1.419 -0.497	0.011 0.015	-2.863 -0.682	-1.652 -0.473	-7.192 -0.737	-1.770 -0.499
$CaCO_3$ SATURATION INDICES							
Equilibrium Ca method	-0.810	0.365	0.807	0.537	-0.420	-6.337	-0.315
Equilibrium pH method	0.482	0.837	1.155	0.974	0.787	0.274	0.720
GIBB'S PLOT							
Mechanism Controlling the Chemistry	Rock Interaction	Evaporation	Rock Interaction	Rock Interaction	Rock Interaction	Rock Interaction	Rock Interaction
HANDA'S CLASSIFICATION							
Hardness	A3 Permanent	A3 Permanent	A3 Permanent	B3 Temporary	A3 Permanent	B3 Temporary	A3 Permanent
Salinity	C4 High	C5 V.High	C4 High	C3 Moderate	C3 Moderate	C3 Moderate	C3 Moderate
Sodium hazard	S3 High	S3 High	S2 Moderate	S2 Moderate	S2 Moderate	S3 High	S2 Moderate
USSL CLASSIFICATION							
Salinity	C3	C4	C4	C2	C3	C3	C3
Sodium hazard	S2	S2	S2	S2	S2	S2	S2
STUYFZAND'S CLASSIFICATION							
Water Type (Based on Cl-)	F-Fresh	F-Fresh-brackish	B-Brackish	F-Fresh	F-Fresh-brackish	F-Fresh	F-Fresh-brackish
Sub-Type (Based on Alk)	ALK-MODERATE	ALK-High	ALK-MOD-HIGH	ALK-MOD-HIGH	ALK-MOD-HIGH	ALK-MOD-HIGH	ALK-MOD-HIGH
Facies	NA+K SO4	Na+K Mixed	Na+K Cl	Na+K Mixed	NA+K Mixed	Na+K SO_4	Na+K Mixed

CONCLUSION

From the above discussion, Secondary parameters and Hydrochemical facices are clearly evident that, the Ground water quality of the Mysuru City was moderately damaged by improper management of Urban Wastewater in the City, The mitigation measures along with long term monitoring complex will necessary to avoid further contamination of the Ground water in Mysuru. It is seen that improvement can be achieved in effective water quality managements to adopt the alternatives by using modern tools to effective management of wastewater treatment plants.

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