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Study of Salinity Pollution due to Irrigated Agriculture from Sangamner Area, Ahmednagar District, Maharashtra, India

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Abstract. Irrigation plays a critical role in providing food and fiber for the growing population in India. Irrigation is not only a science concerning with better use of water but it is an art of management. A tendency among farmers in dry regions is to over – irrigate which causes rise in the groundwater levels resulting in degradation of soil and groundwater resources. This also leads to continuous decline in agricultural productivity. In view of this, an attempt is made to study the salinity pollution due to irrigated agriculture in Sangamner area. 25 groundwater samples were analysed for various parameters such as pH, EC, TDS, Ca^{2+}, Mg^{2+}, Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-} and NO_3^- during pre and post monsoon season. pH and electrical conductivity show higher values in pre monsoon due to increase in the ionic content of groundwater. High proportion of Cl, SO_4 and NO_3 in irrigated agriculture sector in comparison with non-irrigated agriculture. Amongst the cations, Ca and Na are most predominant constituents. On the basis of TDS, the groundwater is classified as fresh, slightly saline to moderately saline and very saline in character. In general saline groundwater is confined to irrigated agriculture and that of fresh to non – irrigated agricultural zone. Increase in the concentration of nitrate during irrigation was associated with a higher level of irrigation return flow (IRF). Salinization and/or alkalization of soils and groundwater, waterlogging and nitrate pollution has been identified as agricultural irrigation effects on the groundwater quality in the area. The soils from the study area are easily waterlogged during rainy season. The problem is further aggravated due to decrease in depth of water table by injudicious irrigation and canal seepage. The education and training programmes must receive due priority to farmers regarding the effects of intensive agricultural irrigation on groundwater to avoid further degradation of soil and groundwater resources.

Keywords: Irrigation return flow (IRF), Salinization of groundwater, Nitrate pollution, Waterlogging.

1. Introduction

Agriculture is the biggest user of water worldwide. 70% of global freshwater withdrawals are for irrigation, rising to more than 90% in some arid countries. Due to poor management of irrigation in many areas of the world only an estimated 30-35 % of the water withdrawn for farming reaches the crop and rest is lost from irrigation channels by evaporation and through run off from the field. This run off of polluted irrigation water containing sediments, pesticides and nutrients leaches through the soil and pollute groundwater resources. Over-irrigation that leave water standing in fields can enhance the incidence of water born parasitic infections such as Bilharzia (Schistosomiasis) (www.panda.org/freshwater). The intensification of agriculture can lead to groundwater pollution related to the increased use of pesticides and chemical fertilizers.

Groundwater is the most important source of domestic, industrial and agricultural water supply in the world. Exploitation of surface waters has reduced, ensuring an increasing reliance on groundwater abstraction due to increasing pollution with the concomitant rise in the cost of water treatment. Groundwater

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quality reflects inputs from the atmosphere, soil and water rock reactions as well as pollutant sources from agriculture, domestic and industrial waste [1]. The last 20-30 years have witnessed a ‘global boom’ in groundwater use for irrigation in areas subject to extended dry seasons and regular droughts. In India the groundwater irrigated area has increased 500% since 1960 [2]. Today irrigated agriculture is the largest abstractor and consumer of groundwater with almost 40% of all cultivated land under irrigation with large groundwater dependent. The nations with the largest groundwater use are India (39Mha) and China (19Mha) [3].

Many researchers [4]-[11] studied various aspects of irrigated agriculture induced problems on the groundwater quality such as salinization and/or alkalization, waterlogging and nitrate pollution. There is a fairly good amount of literature available on impact of irrigation on the soil and groundwater chemistry. However, little or no attention has been paid on such studies in the Sangamner area. Therefore, the present investigation will be useful in finding the remedial measures of the problems created by man-made activities in the area. Moreover, Sangamner area is also experiencing such irrigation-induced problems with its unique landform configuration displaying prohibitive slopes. Scanty and low rainfall condition in the area developed typical condition. However, irrigation not only caused the overall change in the economy as well as general development of the area, but also affected agricultural ecosystem. Lack of proper management of water, land and the water resources have started deteriorating the system, particularly in the downstream part of Pravara River. In view of this, it was decided to study salinity pollution due to irrigated agriculture in the study area.

2. Study Area

Sangamner area is located in the northern part of the Ahmednagar district of Maharashtra State. The tahsil lies between 18°36' N to 19° 1’N latitude and 74° 1’W to 74° 56’W longitude. The Sangamner is Taluka head quarter located on the confluence of the Mahalungi and the Pravara River (Fig.1).

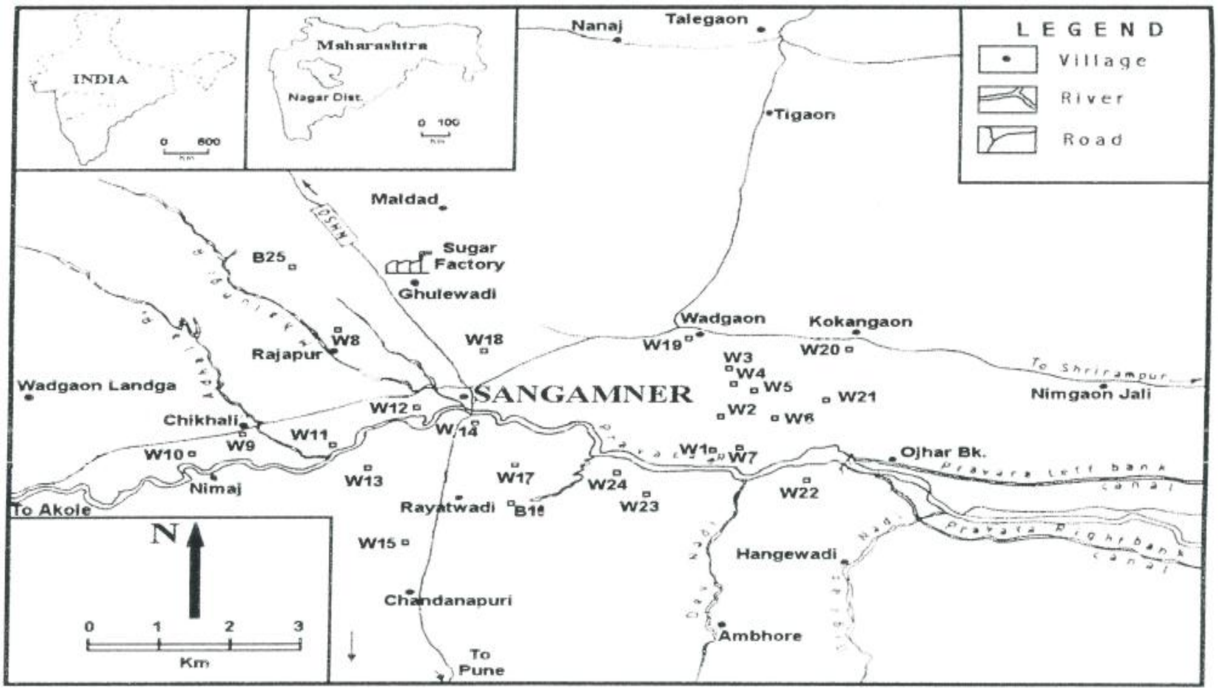

Fig 1 : Locations of groundwater sampling stations in the Sangamner area.

3. Materials and Methods

The samples from 25 groundwater sampling stations were collected on the basis its use for irrigation as well as for drinking purposes over two seasons. The samples were collected in the bottles of one-liter capacity. The pH and electrical conductivity (EC) were measured in the field. The analysis was carried out in the laboratory by using the procedures given by APHA, AWWA, WPCF. Using titrimetric methods, analysis of chloride (Cl^-), calcium (Ca^{2+}) and magnesium (Mg^{2+}) were carried out. Nitrate and sulphate were analyzed by spectrophotometric methods. The alkali elements like sodium (Na) and potassium (K) were detected by flame photometer (Model $E_1$850 A, Equip - tronics). The data obtained by carrying out chemical analysis for groundwater is presented in Table 1 and 2.

4. Results and Discussion

4.1. Variations in pH and EC

pH of groundwater ranges from 7.4 to 8.4 and 7.9 to 8.9 during pre (winter) and post monsoon (summer) seasons respectively, which indicates weakly to moderately alkaline nature of groundwater. The slight increase of pH can be attributed to the higher proportion of bicarbonates and discontinued supply of CO_2 to cessation of rainfed recharge to the aquifer [12]. This increase in pH also be related to higher ionic content of groundwater. The ground water from study area was showing higher EC values which indicates increase in the mineralization content of water. The EC values ranges from 900 to 11100 µS/cm and 580 to 10360 µS/cm during pre and post-monsoon respectively. Lowering of EC values in post - monsoon could be due to dilution effect caused by rainfed recharge during the monsoon season leading to higher groundwater level. The higher values in EC during pre monsoon reflects concentration effect. The high conductivity in some of the samples (S.No. W4,W5,W6,W7,W9 and W10 etc) in the downstream part of the river is likely due to prolonged and extensive agricultural practices such as irrigation coupled with inherent geological conditions acquiring high concentrations of dissolved minerals. Sarma and Swamy (1981) [13] classified the groundwater on the basis of EC as low, medium class I, Medium class II and High conductive class III. On this basis the groundwater from study area can be classified as given Table 3.

Table 1: Physico-chemical characteristics of groundwater during **Pre-monsoon (May 14).**

S. N.	WT	pH	EC	TDS	Na	K	Ca	Mg	Cl	HCO_3	SO_4	NO_3
W1	7.6	8.6	4730	3027	210	2	120	136	413	561	145	37
W2	9.1	8.8	991	634	38	1	56	39	93	181	67	48
W3	11	8.3	6020	3853	216	1	303	296	743	440	145	32
W4	9.1	8.5	11100	7104	468	2	405	409	1458	419	150	28
W5	11	8.5	10330	6611	432	3	240	353	1510	548	149	48
W6	9.1	8.4	7530	4819	312	1	212	275	813	553	145	36
W7	10	8.5	6870	4397	324	1	148	200	576	653	142	36
W8	19	8.6	3950	2528	128	0	136	178	488	472	107	46
W9	15	8.3	7600	4864	360	1	237	290	1120	528	141	81
W10	14	8.3	8050	5152	392	1	220	241	1157	544	145	75
W11	15	8.3	5510	3526	200	1	100	161	620	641	135	55
W12	21	8.4	3860	2470	168	6	124	97	413	508	103	26
W13	14	8	4830	3091	160	1	237	244	638	532	97	60
W14	13	7.9	5130	3283	88	3	433	229	927	375	112	60
W15	12	8.1	5510	3526	64	1	233	303	893	307	76	30
B16	-	8.1	6200	3968	130	0	407	277	955	375	130	55
W17	11	8.1	6250	4000	90	1	397	351	971	379	136	37
W18	18	8.6	2810	1798	116	0	120	146	274	561	52	42
W19	15	8.2	2870	1837	20	0	225	145	341	395	85	76
W20	12	8.3	3900	2496	50	2	231	240	547	419	75	55
W21	9.1	8.2	6380	4083	76	1	422	285	930	286	145	34
W22	17	8.3	4870	3117	162	1	244	175	349	633	139	54
W23	3	8.7	1670	1069	44	1	208	29	129	298	64	65
W24	3	8.5	2240	1434	100	1	120	49	129	540	54	44
B25	-	8.9	900	576	32	0	92	51	53	282	24	36
Min	3	7.9	900	576	32	0	92	29	53	282	24	26
Max	21	8.9	1110	7104	468	6	405	409	1510	653	150	81

Table 2: Physico-chemical characteristics of groundwater during **Post-monsoon (Nov 14).**

S. N.	WT	pH	EC	TDS	Na	K	Ca	Mg	Cl	HCO_3	SO_4	NO_3
W1	3	8.2	4630	2963	260	1	19	25	129	689	161	36
W2	2.4	8.2	6420	4109	360	2	25	35	198	602	166	29
W3	7.6	7.6	5320	3405	172	2	116	93	272	393	164	56
W4	6.1	7.7	10360	6630	380	3	148	131	533	398	167	40
W5	5.8	7.7	10250	6560	380	2	87	146	598	536	165	72
W6	3	8	6620	4237	284	2	65	82	302	602	166	47
W7	2.7	8.3	6770	4333	332	1	38	35	216	755	159	68
W8	19	8.2	3780	2419	134	1	25	54	103	485	151	52
W9	7.6	8	6690	4282	280	1	31	18	253	538	157	44
W10	9.1	7.9	7240	4634	272	2	44	24	193	592	153	66
W11	12	8	4870	3117	260	2	38	35	142	614	158	34
W12	13	8.2	3970	2541	208	1	28	29	107	568	149	40
W13	11	7.6	4470	2861	136	2	51	53	149	466	123	57
W14	14	7.4	4640	2970	68	3	52	109	220	252	141	62
W15	13	7.8	4740	3034	130	2	64	68	239	257	124	37
B16	-	7.8	4600	2944	124	2	51	69	176	339	154	44
W17	7.6	7.5	5700	3648	110	2	88	111	369	383	156	29
W18	23	8.4	2770	1773	122	2	20	31	105	457	76	36
W19	15	7.8	2140	1370	72	2	48	56	90	364	123	46
W20	12	8	3300	2112	116	2	51	37	156	318	122	61
W21	8.5	7.6	4500	2880	124	1	172	79	300	362	155	65
W22	20	8	4170	2669	140	1	48	44	133	499	156	53
W23	4.5	8.2	1860	1190	120	1	30	30	122	359	129	48
W24	9.1	8.2	1680	1075	126	1	21	57	71	436	109	36
B25	-	8.4	830	531	28	0	26	14	30	140	53	29
Min	3	7.4	830	531	28	0	19	14	30	140	53	29
Max	23	8.4	10360	6630	380	3	172	146	598	689	167	72

Note: 1. All values of the constituents are in mg/l, except pH and EC (µS/cm); 2. W- Dugwell, B- Borewell. 3. Water Table (WT) depth in meters.

Table 3: Classification of groundwater on the basis of electrical conductivity.

Class	Conductivity range µS/cm	Post Monsoon(No. of wells)	Pre Monsoon (No. of wells)
Low conductive	<500	Nil	Nil
Medium conductive (Class I)	500 - 1000	**1 (4% Wells)** W25	**2 (8% wells)** W2, W25
Medium conductive (Class II)	1000 – 3000	**4 (16% wells)** W18, W19, W23, W24	**4 (16% wells)** W18, W19,W23,W24
High conductive (class III)	>3000	**20 (80% wells)** W1, W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13, W14, W15, W16, W17, W20, W21, W22.	**19 (76% wells)** W1, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13, W14, W15, W16, W17, W20, W21, W22.

The majority of the samples (i.e. 80% in post monsoon and 76% in pre - monsoon) belong to High Conductive class III (>3000 µS/cm) given by Sarma and Swamy (1981) [13] indicating built of salinity in the groundwater. The higher values of EC from downstream areas reflect low flushing rate and sluggish groundwater movement. Due to rolling topography and relatively higher gradients in the upstream areas of the catchment the conductivity values are of lower order, which imply comparatively higher rates of flushing of salts from these areas. The remaining samples belong largely to Medium Conductive class II, followed by Medium Conductive class I. No samples in post-monsoon and pre monsoon season belong to Low Conductive class (i.e. <500 µS/cm). These samples were from non-irrigated agricultural areas situated on the plateau. The some samples in pre-monsoon show direct shift to Medium conductive class suggesting control of evaporation on the hydro chemical diversity in the area.

4.2. Variations in Cationic Constituents

Calcium concentration in the groundwater varies from 32 to 468 mg/l and 28 to 380 mg/l during pre and post - monsoon respectively. Ca is found to be higher during post - monsoon season is due to dissolution of precipitates of $CaCO_3$ and Ca Mg $(CO_3)_2$ during recharge. The Mg value varies from 29 to 409 mg/l and 14 to 146 mg/l during pre and post-monsoon respectively. Mg is expected to come from in congruent dissolution of pyroxene in the basaltic lithology. The Ca and Mg have been largely derived from water - rock interaction in the alluvial lithology. In the alluvium, the Ca and Mg have been associated with the carbonate nodules forming comparatively higher proportion [14]. The sodium content of the groundwater ranges from 28 to 380 mg/l in pre-monsoon season and 28 to 380 mg/l in post - monsoon season. The K concentrations are negligible although slight increase is noticed in pre-monsoon season (Table 1).

4.3. Variations in Anionic Constituents

The Cl value ranges from 53 to 1510 mg/l and 30 to 598 mg/l during pre and post-monsoon respectively. The SO_4 content of the groundwater ranges from 24 to 150 mg/l in pre-monsoon and in the post - monsoon it varies from 53 to 167 mg/l. Sulphate is higher in post-monsoon season may be due to action of leaching and anthropogenic activities. SO_4 is not active in summer season because it is mainly derived from fertilizer sources and farmers do not generally use fertilizers in summer. In the present study, HCO^-_3 value ranges from 282 to 653 mg/l and 140 to 689 mg/l during pre and post-monsoon respectively. HCO_3 was higher during post- monsoon season may be due to action of CO_2 upon the basic material of soil and rock since the origin of HCO_3 can be related to the aquifer lithology. It is further observed that in the intensive irrigation areas, excess use of nitrogenous fertilizers has hastened the process of nitrate built up. Around sugar factory areas mixing of effluents with groundwater is responsible for high order of nitrate values. It is also observed that nitrate pollution is localized to certain areas in the rural belt. This is attributed to the nitrogen excreted by cattle in the farm and dairies where large number of buffaloes and cows are housed in relatively small areas. In some villages during summer, it is a common practice to allow cattle herds swimming in the ponds or washed near wells. An excreta of these animals gets accumulated and is leached by rainfall causing higher nitrate pollutions of waters. The extent of such groundwater pollution depends on bio gradation and soil and rock strata characteristics through which percolation takes place. It is known that nitrate directly does not affect human health. However, when certain bacteria are present in the digestive tract may convert the nitrates into highly toxic nitrites. In turn, nitrate can lead to Blue Baby syndrome (*Methamoglobinema*) which can be fatal during first three months of life [15]. There is need to generate public awareness about nitrate pollution in the area.

4.4. Salinity Pollution and Irrigated Agriculture

Increase in the concentration of dissolved salts in the water attributable to both natural and human induced factors, leads to the process of salinization [16]. However, salinization is usually caused by mismanagement of irrigation. Salinizations badly affecting physical properties of soils and plant growth. It also leads to reduction in crop yields. Salinisation causes corrosion of plumbing, industrial boilers and household appliances and thereby increases the water treatment costs, which affect industrial and municipal users. There is deterioration in drinking water quality due to salinisation [17].

Hem (1991) [18] has classified the waters into four categories based on TDS values. The groundwater from the study area is classified (Table 4).

Table 4: Classification of saline ground waters on the basis of TDS.

Nature of water	TDS mg/l	Post Monsoon	Pre - Monsoon
Fresh water	> 1000	W25 = 01 (4%)	W2, W25 = 02 (8%)
Slightly saline	1000 - 3000	W1,W8,W12,W13,W14,B16,W18, W19,W20,W21,W22,W23,W24 = 13 (52%)	W1,W8,W12,W18,W19,W20,W23, W24 = 08 (32%)
Moderately saline	3000 - 10000	W2,W3,W4,W5,W6,W7,W9,W10, W11,W15,W17 = 11(44%)	W3,W4,W5,W6,W7,W9,W10,W11 ,W13,W14,W15,B16, W21,W22 = 15 (60%)
Very saline	10000 – 35000	Nil	Nil
Brine	> 35000	Nil	Nil

Out of 25 wells sampled during post-monsoon, one (4%) sample belongs to fresh water and two (8%) samples during pre monsoon. Higher percentage of wells in pre-monsoon season display moderately saline category i.e. 44% in post monsoon and 60% in pre monsoon. The wells from non-irrigated agricultural sector largely show fresh water characteristics. This indicates that there is large-scale salinization of ground water in the irrigated area. From the filed evidences it appears that salinization is controlled by physiography, geology and land use. This is because the presence of alluvium, flat topography and intensive irrigation has lead to the problem of salinization in the area. In general, the backwater area of Ojhar weir small-scale dam shows more degradation of water quality. The observations show that the area with TDS less than 1000 mg/L (S. No.W25) lies in the upper part of the basin as well as in the non-irrigated agricultural region. Intensive salinization in the downstream part may be attributed to waterlogging in the area. The saline water is produced possibly due to evaporation, as the water table is located at shallow depth (4 to 5feet). The low salinity of water is observed in the upstream part possibly indicates faster circulation of ground water.

5. Causes of Salinity Pollution in the Area

The locations of soil and groundwater salinization identified in the area demonstrate the existence of salinity problem. Salinization is a cumulative effect of various parameters such as climate, topography, geology, over-irrigation, irrigation practices, quality of irrigation water, restricted drainage, use of chemical fertilizers, landuse and waterlogging have played an important role in the development of saline soils in the area.

5.1. Climate

The Sangamner area is characterized by semi-arid climatic conditions with average rainfall not exceeding 500 mm. with maximum temperature as high as 42^{0}C. Since it falls under the rain shadow zone having scanty rainfall thereby leaching of soils does not taken place effectively. These salts accumulated within the area are probably added to groundwater during wet period. In addition, reduction in the flow of river is due to impoundment of water at Bhandardara reservoir has further reduced the flowing rates of the salts. Furthermore, the impoundment of water at Ojhar weir along with the siltation has restricted the movement of salts from the area. Thus, high temperature favoring higher rate of evaporation, lack of surface flow condition, congestion of drainage conditions and siltation in the Ojhar weir seems to be hastened the process of salinization of ground water and soils in the area.

5.2. Geology

The soils from the area are derived from basaltic rocks, which are rich in bases. Therefore they are potentially able to supply very large amount of calcium, magnesium and sodium salts. Due to introduction of irrigation, the dissolution of these bases has been accelerated. As a result of this the groundwater then charged with salts heavily with these salts. In addition, the salts leached from the upper parts of the area are further accumulated in the down land leading to salinization of both, soil and groundwater resources. Due to flat topography of alluvial aquifers in the downstream part of the area, free natural drainage is absent. This leads to increased residence time and sluggish ground water movement producing salinization.

5.3. Use of Chemical Fertilizers and Nitrate Pollution

Heavy application of fertilizers along with irrigation facilities has also contributed to salinity problem. Commercial fertilizers yield chloride, sulphate, nitrate, phosphate, calcium, potassium, magnesium, ammonium and sodium ions in various amounts increasing their concentration in groundwater. Excessive use of fertilizers particularly in soils under intensive monoculture tends to lose organic matter and their ability to retain moisture. Thus, becoming more susceptible to erosion and ultimately losing their fertility and productivity. However, the solubility of phosphate fertilizers is low and it is adsorbed on the soil. Potassium ions from the potash fertilizer are also very well adsorbed on the soil. On the contrary, neither physical nor chemical sorption of nitrate ions occurs with nitrogen fertilizers. Their absorption is predominantly biological. However, the plants through the roots absorb part of nitrogen fertilizer and some part is transformed into cell walls of microorganism. However, this mechanism of nitrate removal is insignificant in soil environment. Overall, the nitrate from fertilizer percolates into the groundwater thereby increasing the nitrate pollution. Majority of the irrigated area under study has been occupied by sugarcane. It encourages using excess of irrigation water, over dose of chemical fertilizers irrespective of crop requirement and soil properties. This has disturbed the quality of soil and groundwater resulting into emergence of saline tract within the irrigated part of the region.

5.4. Landuse

In any irrigated area, assessment of current land-use is important because it has direct bearing on the water resource utilization pattern [19]. However, in the area, land use pattern, unique geological and topographic system have considerable impact on the soil and groundwater quality. The high value crops like monoculture long term crop like sugarcane followed by vegetables like tomato, bhendi, cauliflower, cabbage, bringles etc have been cropped in the irrigated land use. Such land-use encourages the application of fertilizers and pesticides combined with the changes in the soil and groundwater chemistry. However in the hilly area, it is observed that part of the traditional agriculture have been responsible for degradation of the land. The degradation includes deforestation coupled with loss of structure, soil erosion and depletion in soil fertility. The barren, rocky and typical stony wasteland is observed in this area. The large patches of scrubs are seen near the villages like Jorve, Kolhewadi, Rahimpur and Ojhar (Fig 1). These scrubs are *Prosopis juliflora*, reeds etc. are all along the major drainage/stream courses in the region which is closely associated with salt affected lands.

5.5. Waterlogging

Ministry of Water Resources, Government of India, 1991 suggested the norms for categorization of waterlogged areas. If the depth of water is <2m, then area is waterlogged, if it is 2-3m, potentially waterlogged and if it is greater than 3m, it is safe. Based on this criteria, 23 well samples were analyzed from study area. It is observed that out of 23 wells, 4 (17.39%) are potentially waterlogged from the area and the remaining wells are safe. This indicates that nearly 17% area is under threat of potentially waterlogged. In general, the downstream part and backwater area of Ojhar weir (Fig 1.) showed more potential of waterlogging which further leads to intensive salinization and/or alkalization problem in the area.

6. Conclusion

The effect of irrigated agriculture have demonstrated that it has serious effect on the groundwater quality. The pH and EC showed higher values in pre monsoon due to increase in the ionic content of groundwater. Rolling topography and relatively higher gradient in the upstream areas of the Pravara River basin leading to higher rates of flushing display low EC values. EC is higher in the central and downstream part of the basin suggests sluggish groundwater movement and built up of salinity due to low flushing rates. Increase in the values of cationic and anionic constituents in pre monsoon and decrease in post monsoon seasons suggests concentration dilution effect attributable to climatic factors. The higher values of TDS have indicated that there is considerable effect of irrigated agriculture on the groundwater quality. The TDS values clearly indicated slightly saline to moderately saline groundwater properties. Groundwater quality is strongly influenced by bed rock geology and climate but may also be attributed to the effect of salinity pollution due to excess irrigation. Adequate drainage and leaching, selection of salt tolerant crops, blending of saline water with good quality of water, use of manures and mulching can be adopted to improve the salinity pollution soils in the area. Frequent awareness and training programs for farmers can be arranged to avoid further degradation of soil and groundwater resources.

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