Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2013, 5(11):726-731

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Determination of water quality index and fitness of urban water bodies in Bilari town of Moradabad (Uttar Pradesh)

Usha[*1], Shamim Ahmad[1] and Pramendra Kumar[2]

[1]*Department of Chemistry, Bareilly College, Bareilly, India*
[2]*Applied Chemistry Department, M. J. P. Rohilkhand University, Bareilly, India*

ABSTRACT

In the present study, water quality Index (WQI) calculated and intended of the water bodies to ascertain the quality of water for public health in Bilari town of Moradabad district, Uttar Pradesh, India. This study deals the influence of environmental parameters of water quality of different water bodies. There are many ways to evaluate the quality of water as deemed fit for drinking and irrigation purpose. WQI indicating the water quality in terms of index number which offers a useful representation of overall quality of water for public use or for any other intended applications. A number of parameters affect the usability of water source for particular purpose. In this study water quality index is determined on the basis of various physico-chemical parameters. From the foregoing observation of the physico-chemical parameters, it may be concluded that the water bodies show the characters of eutrophication.

Key words: Ground water, WQI, physico-chemical analysis, Bilari (Moradabad)

INTRODUCTION

The fresh water is of vital concern for mankind, since it is directly or indirectly linked to human welfare. The surface waterbodies are most important sources of water for human activities. But unfortunately under several environmental stress particularly pollution, the waterbodies are being threatened as a consequence of developmental activities. The Water Index Quality (WQI) is one of the most effective parameter to assess the quality of drinking water [1-3]. Many scientists reported countrywide data for WQI [4-5] with the apprehension that the ground water is going to pollute regularly. The data obtained through quantitative analysis and WHO water quality standards [6] were used for calculating water quality indices. The objective to calculate WQI and comparing it with the standard is to assess drinking water quality and contamination at Bilari, Moradabad (Uttar Pradesh) India and variation of drinking water quality in different sessions on the basis of calculated values of water quality index.

Bilari tehsil is located at the route on Moradabad to Chandausi and has nearly equal distance from Moradabad and Sambhal districts. Bilari is located at $28^0$37'N and $78^0$47'E, and it is situated an altitude of about 200 meter from sea level and the slop of the surface is from north to south. The area is characterized by periodic occurrence of hot summers, moderate rains and dry winters. The climate of Bilari is affected by Himalayan terrain, and it is rich in small waterbodies and most of the agricultural lands are dependent on these for irrigation. Bilari is far from the rural areas and under rapid development of modernization, industrialization and population growth, during last decade, although it is an agricultural area. Some small scale industries and application of various fertilizers in the harvesting as well as cultivation of different regional crops are causing the pollution in the ground water, especially water

contamination in the area concern. Therefore, the present study urgently has drawn attention toward this region for taking necessary steps to minimize the adverse impacts likely to occur due to the water pollution.

EXPERIMENTAL SECTION

A series of ten different sites at Bilari were designated in order to determine the physico-chemical characteristics of ground drinking water samples in different seasons (winter, summer and rainy season). The samples were collected in year 2011 in three different months (January, June and September months) following the standard methods prescribed for sampling. The standard methods and procedures were followed for quantitative estimation of water quality parameters [7-8]. All chemicals used in the analysis are of Anal-R grade. The standards prescribed by WHO were used for the calculation of water quality indices. Seventeen water quality physico-chemical parameter, whose standards are as per WHO guidelines, were analyzed quantitatively in all the drinking water samples collected at Bilari, and water quality indices were determined. Details of the sampling sites are given in Table-1.

Table-1:- Details of the sampling locations

S. No.	No. and name of site	Location of site	Type of hand pump	Depth of Boaring (Approx.)	Type of source	Apparent water quality	Usage of water
1	(I)	Bilari-I	IM-2	35 meter	Only water source	Neat and clear with good taste	Used in domestic applications
2	(II)	Bilari-II	IM-2	36 meter	Only water source	Clear with bad odour.	Publically used for cattle
3	(III)	Bilari-III	IM-2	33 meter	Complementary source	Water turbid on standing	Numbers of user are very less
4	(IV)	Kundarki	IM-2	38 meter	Only water source	Clear water	Used for all domestic purposes including drinking
5	(V)	Sahaspur	IM-2	34 meter	Only water source	Clear water but not good in taste	Used for all living applications
6	(VI)	Baniakher	IM-2	32 meter	Only water source	Water color turns yellow on standing	Exclusively used for drinking purpose
7	(VII)	Thamla	OHP	28-30 m	Only water source	Neat and clear	Extensively used for drinking and household application
8	(VIII)	Jargaon	IM-2	37 meter	Only water source	Water is clear but having hardness	Moderately used for drinking, washing and bathing
9	(IX)	Gunthal	IM-2	34 meter	Complementary source	Neat and clear	Extensively used for drinking and other purposes
10	(X)	Kuankhera	OHP	30 meter	Only water source	Water becomes turbid on standing	Publically used pump

Note: *IM-2: Indian Mark-II machine, OHP: Ordinary Hand Pump*

The drinking water samples collected from ten different sites at Bilari in three different seasons (January'2011, June'2011 and September' 2011), and WQI were calculated using the methods proposed by Horton, and modified by Tiwari etal. [9-10]. According to role of various parameters on the basis of importance and incidence on the overall quality of drinking water, the rating scales were fixed in terms of ideal values of different physico-chemical parameters. Even if, they are present, they might not be the ruling factor. Hence, they were assigned zero values [11]

For calculating WQI, the following four expressions were applied:

(A) Quality Rating, $Q_N = 100*[(V_N - V_I)/ (V_S - V_I)]$ Eq. (1)

Where,

V_N : actual amount of n^{th} parameter

V_I : the ideal value of this parameter

$V_I = 0$, except for pH and D.O.

$V_I = 7.0$ for pH; $V_I = 14.6$ mg/L for D.O.

V_S: recommended WHO standard of corresponding parameter,

(B) Unit weight (W_N) for various parameters is inversely proportional to the recommended standard (S_N) for the corresponding parameter.

$W_N = K/S_N$ Eq. (2)

Where,

S_N: World-widely accepted drinking water quality standard prescribed

by WHO and K is a constant.

$$\sum_{N=1}^{N=17} S_N W_N = 1, \text{considered here}$$

(C) Sub-Indices, $(SI)_N = (Q_N)^{W_N}$ Eq. (3)

(D) The overall WQI was calculated by taking geometric mean of these sub-indices.

$$WQI = \sum_{N=1}^{N=17} S_N (SI)_N = \sum_{N=1}^{N=17} S_N (Q_N) W_N$$

or

$$WQI = \text{antilog}_{10} \left[\sum_{N=1}^{N=17} S_N W_N \log_{10} Q_N \right]$$

---------- Eq. (4)

To include the collective role of various physico-chemical parameters on the overall quality of drinking water, quality status is designated on the bases of calculated values of water quality indices. On the basis of a number of water pollution studies, the following assumptions were made with the reference to evaluate the magnitude of contamination or the quality of drinking water [12-13]. The suitability of water for drinking and other human purpose is classified as in Table-2 [14-15].

Table-2: Water Quality Index (WQI) and status of water quality

S.No.	WQI level	Water quality status
1.	0-25	Excellent water quality
2.	26-50	Good water quality
3.	51-75	Poor water quality
4.	76-100	Very poor water quality
5.	>100	Unsuitable for drinking

Table-3: Parameter wise WHO standards and their assigned unit weight

S.No.	Parameter	WHO standard	Assigned Unit weight (W_N)
1	P^H value	7.0-8.5 (8.0)	0.016381
2	Turbidity (NTU)	5.00	0.026210
3	Conductivity (mS/cm)	0.30	0.436833
4	Total Alkalinity (mg/L)	100.00	0.001310
5	Total Solid, TS (mg/L)	500.00	0.000262
6	Total Dissolved Solid, TDS (mg/L)	500.00	0.000262
7	Dissolved Oxygen, DO (mg/L)	5.00	0.026210
8	Biological Oxygen Demand BOD, (mg/L)	6.00	0.021842
9	Chemical Oxygen Demand COD, (mg/L)	10.00	0.013105
10	Total Hardness (mg/L)	100.00	0.001310
11	Calcium salts (mg/L)	100.00	0.001310
12	Magnesium (mg/L)	30.00	0.004368
13	Free CO_2 (mg/L)	10.00	0.013105
14	Chloride (mg/L)	200.00	0.000655
15	Zinc (mg/L)	3.00	0.043683
16	Iron (mg/L)	0.50	0.262100
17	Fluoride (mg/L)	1.00	0.131050

RESULTS AND DISCUSSION

The physico-chemical parameters with their WHO standard and unit weight (W_N) assigned with the help of Eq-2 written in the text are listed in Table-3 [16-17]. Site wise and parameter wise estimated values (V_N), and calculated quality rating (Q_N) in month of January, June and September 2011 are presented in Tables 4, 5 and 6 respectively. Critical analysis of the data of WQI presented in Table-7 and its comparison with the standard assumptions shows the following facts regarding the level of drinking water quality of underground drinking water at Bilari during the sequence of study contamination throughout the year.

Table 4: Estimated actual values (V_N) and calculated quality rating (Q_N) for January' 2011.

S. N.	Parameter	Site no. 1		Site no. 2		Site no. 3		Site no. 4		Site no. 5		Site no. 6		Site no. 7		Site no. 8		Site no. 9		Site no. 10	
		V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N
1	p^H value	7.5	50	7.02	2	7.4	40	7.27	27	7.5	50	7.3	30	7.2	20	7.35	35	7.11	11	7.25	25
2	Turbidity (NTU)	1.75	35	3.38	67.6	2.75	55	2.12	42.4	2.77	55.4	4.11	82.2	1.99	39.8	3.5	70	2.54	50.8	2.8	56
3	Conductivity (mS/cm)	0.575	191.7	0.667	222.3	0.431	143.7	0.39	130	0.41	136.7	0.593	197.7	0.31	103.7	0.57	190.3	0.312	104	0.659	219.5
4	Total Alkalinity (mg/L)	220	220	371	371	199	199	190	190	225	225	311	311	175	175	295	295	180	180	225	225
5	Total Solid, TS (mg/L)	750	150	1311	26.2	480	96	585	117	530	106	1240	248	451	90.2	1240	248	867	173.4	930	186
6	Total Dissolved Solid, TDS (mg/L)	590	118	1100	220	400	80	460	92	550	110	910	182	412	82.4	957	191.4	625	125	712	142.4
7	Dissolved Oxygen, DO (mg/L)	4.11	109.3	1.5	136.5	4.2	108.3	4.7	1.32	3.91	114.2	2.45	126.6	5.14	98.6	1.57	135.8	3.42	116.5	3.11	119.7
8	Biological Oxygen Demand BOD, (mg/L)	9.2	153.6	5.2	86.8	10.5	175.4	10.8	180.4	10.9	182	7.5	125.3	11.55	193	4.0	67	7.55	126	7.54	125.9
9	Chemical Oxygen Demand COD, (mg/L)	26	260	32	320	26	260	33	330	22	220	40	400	18	180	47	470	32	320	15	150
10	Total Hardness (mg/L)	309	309	412	412	180	180	250	250	170	170	570	570	170	170	535	535	270	270	280	280
11	Calcium (mg/L)	62	62	115	115	31.3	31.3	45.1	45.1	25.2	25.2	75.4	75.4	28.1	28.1	75.8	75.8	50.5	50.5	71.2	71.2
12	Magnesium (mg/L)	22.16	73.8	45.25	141	15.6	52	21.45	70.4	14.14	47	35.7	119	12.20	40.6	60.12	200	22.5	75	30.14	100.4
13	Free CO_2 (mg/L)	35.1	351	45.7	457	15.11	151	15.15	152	15.17	152	45	450	15.11	151	36.4	364	15.71	157	40.61	406
14	Chloride (mg/L)	53.2	26.6	148.7	74.4	31.41	15.7	65.65	32.8	25.1	12.6	164	82	19.72	9.9	168.7	84.4	14.62	7.3	85.55	42.8
15	Zinc (mg/L)	0.72	24	0.9	30	0.93	31	1.00	33	1.1	36.7	2.2	73.3	0.2	6.67	0.6	20	0.2	6.67	0.5	16.7
16	Iron (mg/L)	0.24	48	0.59	118	0.15	30	0.13	26	0.48	96	0.88	176	0.13	26	0.2	40	0.21	42	0.11	22
17	Fluoride(mg/L)	0.33	33	1.20	120	0.61	61	0.81	81	0.65	65	1.5	150	0.75	75	1.11	111	0.52	52	0.75	75
WQI		**118.8**		**164.4**		**94.96**		**88.5**		**109.3**		**177.3**		**75.5**		**129.6**		**78.18**		**128.6**	

Table 5: Estimated actual values (V_N) and calculated quality rating (Q_N) for June'2011

S. N.	Parameter	Site no. 1		Site no. 2		Site no. 3		Site no. 4		Site no. 5		Site no. 6		Site no. 7		Site no. 8		Site no. 9		Site no. 10	
		V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N
1	p^H value	6.95	5.0	6.70	30	7.25	25	7.06	6.0	7.10	10	6.70	30	7.20	20	6.67	33	7.05	5.0	6.88	12
2	Turbidity (NTU)	1.25	25	2.94	58.8	1.25	25	1.44	28.8	1.13	22.6	3.22	64.4	1.62	32.4	2.07	41.4	1.48	29.6	1.17	23.4
3	Conductivity (mS/cm)	0.711	237	0.833	277.7	0.592	197.3	0.40	133.7	0.613	204.3	0.86	285	0.53	175.7	0.658	219.3	0.47	156.7	0.685	288.3
4	Total Alkalinity (mg/L)	225	225	441	441	371	371	284	284	281	281	404	404	236	236	399	399	285	285	402	402
5	Total Solid, TS (mg/L)	810	162	1408	281.6	612	122.4	680	136	534	106.8	1344	268.8	535	107	1340	268	955	191	982	196.4
6	Total Dissolved Solid, TDS (mg/L)	615	123	1087	217.4	520	104	485	97	576	115.2	1044	208.8	464	92.8	965	193	684	136.8	755	151
7	Dissolved Oxygen, DO (mg/L)	3.95	110.9	1.19	139.7	3.52	115.4	3.51	115.5	3.77	112.8	2.20	129.2	3.63	114.3	2.83	122.6	2.95	121.3	2.95	121.4
8	Biological Oxygen Demand BOD, (mg/L)	7.62	127	3.35	55.83	9.62	160.3	7.98	133	8.66	144.3	6.71	111.8	9.22	153.7	4.37	72.8	5.75	95.8	6.82	113.7
9	Chemical Oxygen Demand COD, (mg/L)	28	280	55	550	26	260	36	360	19	190	33	330	18	180	39	390	34	340	15	150
10	Total Hardness (mg/L)	365	365	256	256	257	257	299	299	3 51	351	621	621	251	251	579	579	380	380	555	555
11	Calcium (mg/L)	68.22	68.2	167.9	167.9	49.1	49.1	65.6	65.6	38.05	38.1	150	150	43.25	43.3	126.2	126.3	68.3	68.3	111	111
12	Magnesium (mg/L)	27.65	92.2	43.1	143.6	17.2	57.2	26.2	87.32	17.2	57.3	55.4	184.5	15.2	50.5	57.12	190.4	22.5	72.2	48.6	162.1
13.	Free CO_2 (mg/L)	26.6	266	46.1	461	19.2	192	32.1	321	21.7	217	46.1	461	19.3	193	48.4	484	25.9	259	39.2	392
14	Chloride (mg/L)	52.18	26.0	148.2	74.1	33.5	16.8	75.5	37.8	24.22	12.1	165.8	82.9	23.3	11.7	169.3	84.7	11.8	5.9	87.1	43.6
15	Zinc (mg/L)	0.60	19.99	0.87	28.99	0.81	29.99	0.73	24.3	1.31	43.7	1.90	63.33	0.26	8.7	0.55	18.3	0.16	5.33	0.76	25.3
16	Iron (mg/L)	0.20	40	0.51	102	0.20	40	0.11	22	0.36	72	0.72	144	0.14	28	0.18	36	0.17	34	0.19	38
17	Fluoride (mg/L)	0.43	43	1.07	107	0.42	42	0.85	85	0.56	56	1.28	128	0.85	85	1.14	114	0.38	38	0.81	81
WQI		**135.5**		**185.4**		**118.2**		**93.4**		**130.8**		**202.7**		**109**		**141.3**		**98**		**137.2**	

Table 6: Estimated actual values (V_N) and calculated quality rating (Q_N) for September' 2011.

S. N	Parameter	Site no. 1		Site no. 2		Site no. 3		Site no. 4		Site no. 5		Site no. 6		Site no. 7		Site no. 8		Site no. 9		Site no. 10	
		V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N	V_N	Q_N
1	p^H value	7.79	79	8.15	15	7.58	58	7.72	72	7.8	80	7.82	82	7.67	67	8.10	110	7.7	70	8	10
2	Turbidity(NTU)	2.51	50.2	5.22	104.4	3.26	65.2	2.99	59.8	3.13	62.6	5.3	106.2	2.25	44.9	4.76	95.2	3.75	75.1	3.7	73.9
3	Conductivity (mS/cm)	0.45	148.7	0.509	169.7	0.31	102.7	0.33	110	0.342	114	0.532	177.3	0.28	93.7	0.44	146.3	0.28	94	0.53	178
4	Total Alkalinity (mg/L)	209.1	209.	341	341	181	181	165	165	200	200	300	300	160	160	281	281	161	161	209.1	209.1
5	Total Solid, TS (mg/L)	750	150	1272.1	254.5	419	83.8	550	110	484	96.8	1109	221.8	380	76	1120	224	701	140	901	180.2
6	Total Dissolved Solid, TDS (mg/L)	576	115.2	1014	202.8	290	58	390	78	404.2	80.8	850	170	310	62	915	183	593	118	690	138
7	Dissolved Oxygen, DO (mg/L)	4.75	108.5	2	133.5	4.88	99.5	5.2	99	4.9	100.5	3	120.6	5.5	94.3	2.3	129	4.01	109.3	3.63	114.1
8	Biological Oxygen Demand BOD, (mg/L)	9.2	153.2	5.22	87	10.8	179.9	10.8	179.9	11.5	191.7	7.85	130.8	11.6	192.3	4.2	69.97	8	132	7.81	130.1
9	Chemical Oxygen Demand COD,(mg/L)	25	250	31	310	25	250	30	300	21	210	38	380	15	150	46	460	28	280	12	120
10	Total Hardness (mg/L)	233	233	533	533	159	159	220	220	114	114	500	500	130	130	535	535	254	245	265	265
11	Calcium (mg/L)	56	56	127.5	127.5	37.7	37.7	52.9	52.9	34.5	34.5	120.3	120.3	30.5	30.5	86.6	86.6	58.5	58.5	86.6	86.6
12	Magnesium(mg/L)	22.45	74.75	51.7	172.3	15.6	52	21.45	71.4	14.14	47.03	48.7	162.4	12.2	40.7	65.32	217.5	23.4	77.9	35.1	116.9
13	Free CO_2 (mg/L)	37.5	375	52.8	528	22	220	19.7	197	17.6	176	55	550	19.8	19	44	440	16.5	165	44	440
14	Chloride (mg/L)	55.7	27.83	147.1	73.6	29.8	14.9	59.6	29.8	19.85	9.93	161	80.5	15.9	7.95	174.9	87.5	12.	6.3	79.8	39.9
15	Zinc (mg/L)	0.72	23.93	0.9	30	0.93	31	1.0	33.3	1.1	36.7	2.2	73.3	0.2	6.67	0.6	20	0.2	6.7	0.5	16.7
16	Iron (mg/L)	0.28	56	0.62	124	0.2	40	0.12	24	0.6	120	0.9	184	0.11	22	0.18	36	0.2	40	013	26
17	Fluoride(mg/L)	0.30	30	1.25	125	0.56	56	0.87	87	0.58	58	1.57	157	0.81	81	1.23	123	0.6	60	0.99	99
	WQI	**104**		**170**		**84**		**76**		**106**		**173**		**72**		**114**		**75**		**115**	

The observed ranges of water quality indices are 75-177, 93-185 and 72-170 in the months of January'2011, June'2011 and September' 2011 respectively (Table-7). The data indicate that there are only a few sites provide the ground water suitably fit for drinking and other household purposes, meanwhile almost sites become polluted in extreme summer season (June'2011) and value of WQI exceed to the permissible limits for drinking recommended by WHO. In winter and post rainy seasons, sites no. IV, VII and IX are providing useful water which can be used for drinking. In general, the water quality index values increase in the summer season and water become more contaminated in comparison of other two seasons. This study clearly indicates the eutrophication statuses of all water bodies are unsuitable for human uses. It also observed that pollution load is relatively high during summer season in comparison to other seasons.

Table-7: Comparative WQI data analysis of different collection sites in different season

S.No.	Site no.	Site location	Water Quality Index (WQI) during different season		
			January' 2011	June' 2011	September'2011
1	(I)	Bilari-I	118.8	135.5	104
2	(II)	Bilari-II	164.4	185.4	170
3	(III)	Bilari-III	94.96	118.2	84
4	(IV)	Kundarki	88.5	93.4	76
5	(V)	Sahaspur	109.3	130.8	106
6	(VI)	Baniakher	177.3	202.7	173
7	(VII)	Thamla	75.5	109	72
8	(VIII)	Jargaon	129.6	141.3	114
9	(IX)	Gunthal	78.18	98	75
10	(X)	Kuankhera	128.6	137.2	115

CONCLUSION

On the basis of overall observations and discussions of water quality index (Table-7), it can be concluded that the water bodies show the eutrophication characteristics. In summer season the water quality index is higher in comparison of winter and rainy season for all sampling locations. Therefore, the fitness of ground water in Bilari region is not suitable for drinking and other household application in summer season. During the winter and post

monsoon season the water can be used at few sites (III, IV, VI, and IX), but very near to the upper limits recommended by WHO. The contamination of water is increasing day by day, and the ground water requires purification before use for drinking purpose. Therefore, it is advised that some effective procedures and measures are required for action promptly with potential water quality management plans through which the pollution not water in the Bilari, Moradabad (Uttar Pradesh, India) could be controlled.

REFERENCES

[1] K Kannan. Fundamentals of Environmental Pollution, S. Chand & Company Ltd., New Delhi **1991**.
[2] DK Sinha; AK Srivastava. *Indian J. Env. Prot*.,**1994**, 14(5), 340-345.
[3] SK Pradhan; D Patnaik; SP Rout. *Indian J. Env. Prot*., **2001,** 21(4), 355-358.
[4] DK Sinha; S.Saxena, R Saxena. *Poll. Res.*, **2004,** 23(3), 527-531.
[5] AP Singh; SK Ghosh. *Poll. Res*.,**1999,** 18, 435-439.
[6] WHO, International Standards for Drinking Water, World Health Organization, Geneva,**1971**.
[7] APHA, American Public Health Association, 19th Edition, Washington, D.C., **1995**.
[8] Merck, E., Testing of Water, Darmstadt, Federal Republic of Germany, **1974**.
[9] RK Horton. *J. Water Poll. Cont. Fed.*, **1965**, 37, 300-305.
[10] TN Tiwari; M Mishra. *Indian J.Env.Prot.*, **1985**, 5(4), 276-279.
[11] Usha; SC Agarwal; S Ahmad**.** *J. of Appl. Chem*, **2013**, 4(1), 29-34.
[12] TN Tiwari; SC Das; PK Bose. *J. of M.A.C.T.*, **1986,** 19, 33-41.
[13] N Kumar; DK Sinha. *Int. J. of Environ. Sci.*, **2010,** 1, 253-259.
[14] C Chatterjee; M Raziuddin. *Environ. Pollut. Technol*. **2002**, 1(2), 181-189.
[15] DK Sinha; R Saxena. *J. of Environ. Science & Eng*. **2006,** 478, 157-164.
[16] N Kalra; R Kumar; SS Yadav; RT Singh. *J. Chem. Pharm. Res.* **2012**, 4(3), 1782-1786.
[17] SS Yadav; R. Kumar. *J. Chem. Pharm. Res.*, **2010**, 2(4), 564-568.