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Review Article

Water Security Plan for the Sustainable Development of Water Resources of Kadamat Jalgram, Union Territory of Lakshadweep, South India

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Abstract

The Water Security Plan for the Sustainable Development of Water Resources of Kadamat Jalgram, Union Territory of Lakshadweep, South India has been studied. Kadamat island is the fourth largest of the inhabited islands of the Union Territory of Lakshadweep, with an area of 3.13 km2, where the fragile ground water resource is occurring as lens over marine water. The hydrogeological conditions of Kadamat island is entirely different from that existing in the main land. On the basis of the hydrogeological investigations and other related studies, certain participatory water management programs are to be urgently initiated in the island for the sustainability of water resources of the study area. The aquifers of the Kadamat are organic/coral limestones and sands with depth to the water table ranges between 1.4 and 5.0 mbgl and the ground water occurs under phreatic condition. The phreatic water is exploited by open dug wells and filter point well and depth vary from 1.4 - 5.0 and 1.8 to 6.0 m bgl respectively. The stage of ground water development in Kadamat is 46.7% and comes under safe category of ground water development. The electrical conductivity (EC) ranges from 500 to 15,000 µS/cm at 25oC. Renovation of open dug wells, filter point wells and tanks/ponds, scientific management/conjunctive use of both surface and sub-surface water, rainwater harvesting structures to be made mandatory, awareness campaign and training programmes to be organized at grass root level on water management as aspects and water budgeting at grass root level, thrust will be given to participatory water ground water management, and an integrated water security plan for the Kadamat are to be prepared and executed.

Keywords: Hydraulic Continuity; Hydrogeology; Corals; Electrical Conductivity and Sustainability

Introduction

The Kadamat island is one among the 36 Lakshadweep Islands (LD Islands) located in the Arabian Sea which is about 400 km from the main land (southern tip of the Indian peninsula). There are only 10 inhabited islands and these islands lie between N latitudes 080 00' and 120 13' and E longitudes 71^0 00' and 74^0 00 (Figure 1). Kadamat island having an areal extent of 3.13 km^2 situated between Amini and Chetlat islands and located between N latitudes 11^0 11' 00" and $11^0$15'30" and E longitudes 72^0 15' 30" and 72^0 47' 30". Kadamat is elongated in shape with lagoon on the western side having 550 metres width and 8 Kms length. The Kadamat island having an altitude of 1 to 8 m above the mean sea level. The location map of Kadamat with other LD islands is compiled (Figure 1). The population of Kadamat is 5404 (2011 Census statistics) and among these male and female constitute 2690 and 2714 respectively. The island with a density of 1727, and the island with density among the Lakshadweep islands. The decadal growth rate of Kadamat is 8.34% (2001 - 2011) with literacy rate of 94%.

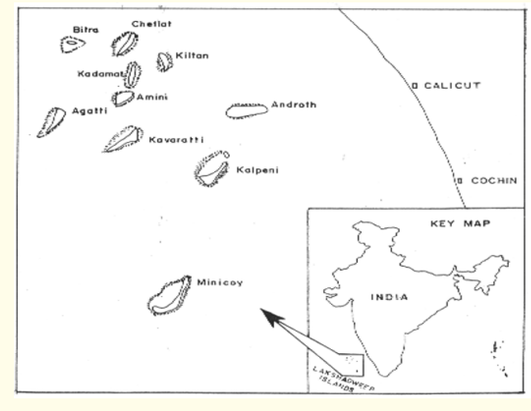

Figure 1: Location map of Kadamat including other Lakshadweep islands.

As per the classification of coral reefs by Charles Darwin, the island of Kadamat coming under atoll with NE-SW trend. The geomorphologic units in the area are lagoon, beach, storm beaches, beach ridges, sand dunes and hinterland. The altitude ranges from 1 to 8 meters above msl with occasional sand dunes. The coral pebbles and boulders occupying the storm beach. The island is devoid of any natural drainage.

The organic coral polyps are responsible for its genesis. The purpose of the study is to propose alternate measures for Water Security Plan for the Sustainable Development of Water Resources of Kadamat Jalgram, Union Territory of Lakshadweep, South India. The sustainability development is the development of resources without sacrificing the needs of future. Its imperatives include developers must recognize the legitimacy of and give full attention to environmental concerns in their plants and projects and environmentalists must recognize the legitimacy of and full attention to economic development concerns in their efforts to protect environment. It is the environmentally sound development with minimum damage to the nature. The sustainability was one the objectives of ninth five-year plan (1992-1997). The UN Conference on Environment and Development/Agenda 21 defines the sustainable development (sustainability) as the development that needs the present without compromising the ability of future generation. The works on sustainability of water resources were carried out by many authors viz. Biswas [1], Peralta and Paralta [2], Fleming and Daniel [3], Navalawala [4], Joji and Nair [5] and many others but the small Island hydrogeological studies were carried out many authors at international and regional levels. These include Barker [6] on Freshwater – Saltwater relation, Peterson [7] groundwater recharge, storage and development on atoll Islands, Chapman [8] the use of water balances for Water Resource Estimation with Special Reference to Small Islands, Dale., *et al* [9]. Coral Island Hydrology, UNESCO (1991) on Hydrology and Water Resources of Small Island, Fackland [10] Review of Ground water Resources of Home and West Island, Cocos (Keeling) Islands, Najeeb [11] Groundwater resources and management in the Union Territory of Lakshadweep- Andrott and Minicoy Islands, Ajaykumar and Ramachandran [12] Resistivity survey for describing the fresh water lenses of Agatti atoll, Lakshadweep, Ajaykumar., *et al*. [13] groundwater resource potential in the union territory of Lakshadweep, Najeeb [14] Integrated Water Management Schemes for Lakshadweep Islands, Mondal., *et al*. [15] Appraisal of groundwater resources in an Island condition, Revichandran., *et al*. [16] Monitoring beach stability and littoral processes at Androth and Minicoy Islands, Lakshadweep. The present study is an attempt to highlight the various measures required to be adopted in the Island of Kadamat for the sustainability of the ground water resources.

Climate and soil

The island experiences tropical wet and dry (as per Koppen) with different seasons like Winter (December to February), Summer (March to May) and Monsoon (Southwest monsoon from June to September and Northeast monsoon from October to November). The Jalgram experiences average minimum and maximum temperature of 26.8^{0}C and 33.1^{0}C respectively. The Kadamat Island experiences normal rainfall of 1554.90 mm and among this 70.6% per cent of rainfall during SW monsoon, 17.8% North-East monsoon period and 11% summer months.

The organic coral limestone has undergone weathering and resulted soil cover over organic coral limestone. The weathered products include coral sands, lagoonal sand and coral mud. As the soils of the Kadamat with high permeability and infiltration capacity, surface run off is meagre in the island but permeability and infiltration capacity decreases towards the peripherals of the Kadamat.

Flora and fauna

There are two types of flora in the area - shallow rooted (grasses, crops and shrubs) or deep rooted (coconut trees). The shallow rooted flora takes hygroscopic water from soil moisture zone coming under zone of aeration/vadose zone. The deep-rooted flora in shallow water table areas, even taking water directly from phreatic zone and behave like typical phreatophytes. The phreatophytes occur in Kadamat and other LD islands where water table is 3 mbgl. In Kadamat island coconut palms are even absorbing ground water 5 mbgl. The coconut palms are the main cultivated crop in the island. The islanders rear cattle especially goat (Capra aegagrus hircus) and poultry.

Materials and Methods

The base map of the island has been prepared by using The Survey of India Topographical Maps (Scale 1:50,000 of 1967-1968. The scanned map was digitized and edited using various Map Info 6.5 tools. Projection and polygonization of units followed the editing. During editing the segment checking like intersection, self-overlap and dead-end corrections were carried out. After polygonization, annotations were given for different polygons and the maps were subjected for further analysis. The various data pertaining to depth to the water table, quality aspects, hydrogeological scenario and related data collected during the microlevel hydrogeological survey in the Kadamat island.

Results and Discussion

The hydrogeology of the of the Island, dynamic Ground Water Resources, quality of ground water, demand for water, present status of ground water development, measures required to be

adopted for the sustainability of ground water in the Kadamat island are briefly discussed.

Hydrogeology of the of the Island

The Kadamat island constitutes organic reefs and their weathered products encircling a lagoon. The hard-organic limestones are seen during ebb tides and at well sections. The geological succession of Kadamat is compiled (Table 1). The organic/coral limestones and sands are the aquifers in Kadamat with depth to the water table between 2 and 3 mbgl and ground water in the Island under phreatic condition. The ground water having the shape of a thin les floating over marine water (Figure 2) and the phreatic water is mainly exploited by open dug wells.

Layer	Formation
Layer 1	Humus
Layer 2	Fine coral sand
Layer 3	Fine conglomerate like oolitic limestone embedded with calcareous shells
Layer 4	Sand layer
Layer 5	Hard organic limestones

Table 1: Geological succession of Kadamat.

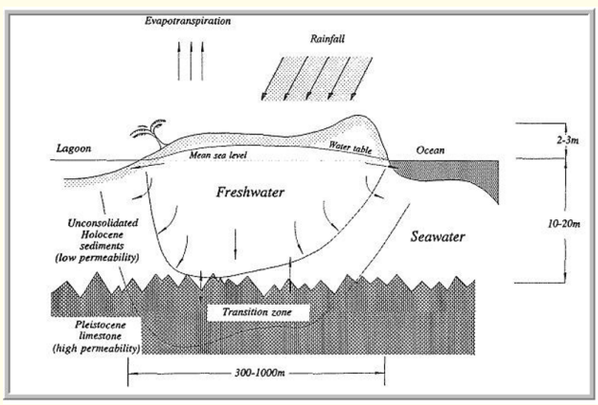

Figure 2: Freshwater lens in small Islands (Exaggerated vertical scale).

In Kadamat ground water is in hydraulic continuity with marine water, it is highly influenced by the diurnal tidal fluctuations. The magnitude of the tidal fluctuation is controlled by coefficient of permeability and proximity to sea. As the island is very elongated and having a width of 0.5 km only, the fresh water occurrence is under threat. The depth to the water level and depth vary from 1.4 - 5.0 and 1.8 to 6.0 m bgl respectively.

Sources of water

The fresh water source in Kadamat is from ground water and is extracted by dug wells with depth of water level a few meters with diameter of 1-2 m. Most of the households of Kadamat with their own wells and the water is utilised for domestic and agricultural purposes. Now a days people use mono block pumps of 0.5 HP for extracting the water.

Dynamic ground water resources

The dynamic ground water resources of Kadamat computed by considering major recharge and draft components. The rainfall is the main recharge component but draft components are domestic water consumption, evapotranspiration (consumptive use) and outflow into the sea. The 20% of the annual water surplus is reserved as buffer zone for reserve during delayed or deficit monsoon years and the details are compiled (Table 2).

#	Annual components of Water Balance	Data
1	Population (Projected as on 2017)	5446
2	Area (Ha)	312.0
3	Normal Monsoon Rainfall (m)	1.355
4	Rainfall Infiltration Factor (%)	30
5	Total Resource (Water Surplus) (Ha.m)) [2*3*4]	126.8
6	ET loss from Trees for 6 non-monsoon months (Ha.m)	33.8
7	Water loss due to outflow to sea [20% of (3) (Ha.m)]	25.4
8	Buffer zone for reserve during delayed or lesser monsoon period [20% of (3)] (Ha.m)	25.4
9	Balance available resource (Ha.m)	42.3
10	Domestic Extraction @100 lpcd [1*100*365] (Ha.m)	19.8
11	Gross Annual GW Extraction (Ha.m)	19.8
12	Groundwater balance available [9-11] (Ha.m)	22.6
13	Stage of ground water extraction [11*100/9]	46.7
14	Category	Safe

Table 2: Dynamic Ground Water Resources of Kadamat (As in March 2017).

Figure 3: Hydrogeological map of the island.

Figure 4: Depth to Water level map of the island (mbgl).

Quality of ground water

The ground water in the Kadamat is alkaline and Electrical Conductivity (EC) ranges from 500 to 15,000 µS/cm at 25oC. The TDS along the periphery of the island and pumping centers is high and dilution occurs during the onset of monsoon. Besides quality is controlled by tides, recharge and discharge (draft), zone of inter face and mixing/transition zone. The quality deterioration more pronounced near mechanized wells than manually drawn and the quality deterioration is mainly expressed in the rise in EC. The quality variation is also caused by pollution from human and livestock wastes, oil spills, domestic and hotel sewerages and wastes generated by human and other organisms. The EC variation is depicted (Figure 5) and the chemical analysis data of observation wells in the island is compiled (Table 3).

Figure 5: Distribution of Electrical conductivity in Kadamat island.

#	pH	EC, µS/cm	TDS (mg/l)	Chloride, mg/l	TH, mg/l	Ca- Hardness, mg/l	Mg-Hardness, mg/l	Alkalinit mg/l	Salinity, mg/l
1	8.05	7260	4066	2350	1250	200	1050	760	4245
2	8.06	3270	1831	950	820	200	620	836	1716
3	7.72	6200	3472	1500	1530	190	1340	840	2710
4	8.1	11240	6294	3700	2100	200	1900	560	6684
5	8.12	3320	1859	950	650	190	460	560	1716
6	7.89	14940	8366	5350	2650	200	2450	792	9665
7	7.79	6650	3724	2000	1510	190	1320	664	3613
8	7.74	9180	5141	2500	2190	180	2010	552	4516
9	7.87	8460	4738	2450	1950	190	1760	552	4426
10	7.84	10110	5662	3050	2360	200	2160	792	5510
11	7.84	2970	1663	620	830	190	640	728	1120
12	7.86	4770	2671	1450	960	200	760	512	2619

13	7.87	2660	1490	600	680	180	500	612	1084
14	7.86	3490	1954	960	840	190	650	556	1734
15	7.89	2960	1658	740	710	200	510	512	1337
16	8.08	2990	1674	730	670	180	490	490	1319
17	7.83	1670	935	250	480	170	310	528	452
18	7.96	2350	1316	560	550	190	360	560	1012
19	7.7	4460	2498	1300	980	190	790	620	2349
20	7.86	1640	918	270	460	180	280	550	488
21	8.1	1850	1036	310	600	180	420	400	560
22	7.9	1460	818	190	400	130	270	400	343
23	8.09	1500	840	210	400	170	230	364	379
24	7.85	1760	986	220	450	170	280	416	397
25	8.05	1370	767	150	500	180	320	412	271
26	7.9	2110	1182	330	550	160	390	456	596
27	8.05	1400	784	140	380	150	230	400	253
28	7.76	1900	1064	250	500	120	380	480	452
29	7.69	1950	1092	280	520	150	370	480	506
30	7.84	1670	935	230	520	190	330	512	416
31	8.1	1250	700	90	330	100	230	352	163
32	8	1400	784	170	430	100	330	364	307
33	7.97	1520	851	180	440	120	320	360	325
34	7.99	1530	857	150	350	100	250	484	271
35	7.8	1180	661	120	360	140	220	360	217
36	7.74	1830	1025	200	520	150	370	504	361
37	7.59	1820	1019	200	540	100	440	496	361
38	7.84	1330	745	160	390	120	270	476	289
39	7.61	1570	879	210	420	160	260	448	379
40	8.07	1560	874	220	430	140	290	376	397
41	7.88	1790	1002	250	530	170	360	400	452
42	7.89	1390	778	100	390	150	240	460	181
43	8.1	2120	1187	380	550	160	390	440	686
44	8.08	1370	767	170	400	140	260	360	307
45	7.92	1140	638	120	380	160	220	408	217
46	8.09	1540	862	140	430	170	260	304	253
47	8.09	1540	862	140	440	180	260	352	253
48	7.93	1500	840	130	400	180	220	344	235
49	7.85	2110	1182	290	570	170	400	472	524
50	7.76	2350	1316	430	660	190	470	408	777
51	7.86	1800	1008	250	560	160	400	420	452
52	8.09	1350	756	140	400	140	260	364	253
53	7.77	2190	1226	370	580	160	420	424	668
54	7.9	1520	851	170	400	150	250	392	307
55	7.68	1580	885	180	430	160	270	400	325
56	8	1290	722	130	330	130	200	408	235

57	8.1	1740	974	200	460	170	290	480	361
58	8.09	1370	767	160	420	140	280	384	289
59	8.1	1440	806	150	330	130	200	360	271
60	8.09	1630	913	240	430	140	290	392	434
61	8.09	1380	773	170	350	120	230	400	307
62	7.88	1690	946	240	560	160	400	456	434
63	8.1	2150	1204	380	580	150	430	500	686
64	7.94	1350	756	140	450	130	320	472	253
65	8.09	1320	739	130	330	140	190	480	235
66	8.1	1300	728	150	380	100	280	432	271
67	8.1	1340	750	150	390	150	240	420	271
68	8.04	1420	795	130	470	140	330	352	235
69	8	1350	756	100	350	150	200	436	181
70	8.1	1740	974	230	450	140	310	376	416
71	7.94	2700	1512	400	730	160	570	570	723
72	8	1650	924	200	430	180	250	384	361
73	7.86	1550	868	180	450	160	290	412	325
74	8.07	1430	801	150	400	150	250	424	271
75	7.93	1240	694	130	360	170	190	368	235
76	7.75	2530	1417	490	750	190	560	584	885
77	7.98	2560	1434	430	650	160	490	536	777
78	7.89	1580	885	230	440	160	280	520	416
79	7.98	1700	952	190	450	170	280	360	343
80	8.1	1590	890	170	400	140	260	448	307
81	7.98	2470	1383	420	650	180	470	520	759
82	7.6	2920	1635	560	790	200	590	592	1012
83	7.9	1320	739	150	430	120	310	360	271
84	8.09	1270	711	100	360	140	220	448	181
85	8.1	2770	1551	580	640	200	440	568	1048
86	7.43	1260	706	140	370	140	230	440	253
87	7.97	1280	717	170	390	130	260	400	307
88	8.11	5290	2962	1210	1330	200	1130	660	2186
89	8	1470	823	180	490	130	360	456	325
90	8.05	3310	1854	780	810	190	620	540	1409
91	7.9	1490	834	180	470	190	280	432	325
92	7.93	2300	1288	400	680	140	540	528	723
93	7.96	1840	1030	200	570	180	390	504	361
94	7.89	2060	1154	350	500	180	320	464	632
95	7.85	1860	1042	250	420	160	260	408	452
96	7.99	1350	756	150	280	150	130	480	271
97	8.05	1470	823	130	380	120	260	384	235
98	7.7	1650	924	200	480	160	320	456	361
99	7.9	1730	969	200	430	120	310	464	361

100	7.88	1840	1030	230	500	170	330	480	416
101	8.04	1770	991	280	430	170	260	476	506
102	8.05	1290	722	150	350	120	230	408	271
103	8.09	1940	1086	330	520	160	360	482	596
104	7.93	1630	913	270	370	150	220	384	488
105	7.94	1620	907	240	390	140	250	384	434
106	7.96	1750	980	220	440	170	270	424	397
107	8.09	4100	2296	1100	770	190	580	540	1987

Table 3: Chemical analysis data of ground water in Kadamat (March 2017).

Demand of water

The people of Kadamat is mainly using the ground water for domestic purposes as there is no major industries in Kadamat except small scale industries associated with coconut. The domestic requirements are highly affected due to increasing salinity during summer and people's demand for water is met from two infiltration galleries/radial collector wells located in the island. The domestic need is further aggravated by the mechanical pumping due to mechanized pumping for construction purposes, pollution from septic tanks, sewages and waste disposal sites. As the island doesn't practice irrigated cultivation the irrigation water demand is zero and the water demand for 5404 Nos of population is computed as 20 ha m.

Present status of development

The available resource in the island is 42.3 Ha.m and islanders use 19.8 Ha.m for domestic purposes and the balance available is 22.6 Ha.m. The stage of ground water development in Kadamat is 46.7% and coming under safe. The population in the Kadamat uses both ground water and rain water for potable purposes. There are 380 rain water harvesting storage tanks, 8 Nos of wells for public water supply and among 1061 households only 130 households are connected with public water supply schemes.

Solutions

In order to enhance the availability of water for the mankind and vegetation measures like harvesting of water and creating awareness to stakeholders on water conservation and quality aspects have to be initiated. For the sustainability of water resources of the Jalgram of Kadamat following indicatives have to be adopted.

- Renovation and desilting of all the water extraction structures like open dug wells, filter point wells and tanks/ponds,
- Scientific management/conjunctive use of both surface and sub-surface water,
- Rainwater harvesting structures to be made mandatory,
- Awareness campaign and training programmes to be organized at grass root level on water management as aspects and water budgeting at grass root level,
- Thrust will be given to participatory water ground water management, and
- An integrated water security plan for the Kadamat to be prepared and executed.

Conclusion

Water Security Plan for the Sustainable Development of Water Resources of Kadamat Jalgram, Union Territory of Lakshadweep, South India has been examined in the work. The various measures urgently required for the sustainability of the meagre ground water resources of Kadamat have been proposed. These include repair, renovation and restoration of existing and abandoned water bodies like well, ponds/tanks, judicious use of ground water, construction of rainwater harvesting tanks, artificial recharge to ground water, mass awareness programs, community-based water monitoring, proper water budgeting (if possible, on a daily time step), and proper plan for water allocation for different sectors as per priority.

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