IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 10, Issue 8, August 2020, ||Series -I|| PP 12-21

Physicochemical properties of Groundwater around Municipal waste disposal sites: a Review

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Received 07 August 2020; Accepted 21 August 2020

ABSTRACT
Background: Groundwater contamination is a serious problem now a day. Groundwater is contaminated due to human and industrial activities. The most neglected cause of water pollution is uncontrolled dumping of Municipal Solid Waste. Leachate from the waste disposal sites is the major groundwater contaminant. The use of contaminated water results in a negative impact on human health. Thus the analysis of the water quality is very important to preserve and perfect the natural ecosystem.This review paper includes the analysis of groundwater for various physico-chemical parameters Viz. pH, Total dissolved solids, electrical conductivity, total alkalinity, total hardness, calcium and heavy metals like iron, chromium, zinc, manganese, nickel. The obtained results are compared with the permissible limits of WHO. The study of physicochemical parameters of groundwater sample suggests that the evaluation of water quality parameters as well as water quality management practices should be carried out periodically to protect the water resources.
Methodology: Systematic searches were done on various scientific databases. And the collected data was analysed carefully.
Conclusion: It was concluded that water was contaminated at most of the sites. The values of EC,TDS and Total Hardness at 38% sites were exceeding the permissible limits as prescribed by WHO. Magnesium, Sodium and Fluoride at 12.6% sites and pH, Potassium, BOD and COD at only 1.5% sites were higher than the permissible limits. Total Alkalinity, Calcium, Chloride, Sulphate, Fluoride and Nitrate at 15.8%,25.3%,26.9%,9.5%,19% sites respectively were not under the permissible limits as prescribed by WHO. However, the values of Ammonia, Phosphate and BOD at 100% sites were under the permissible limits of WHO. The concentrations of Iron,Zinc,Copper,Manganese,Lead,Cadmium,Chromium And Nickel at 28.5%,3.1%,7.9%,11.1%,4.7%,7.9%,12.6% and 1.5% sites respectively,were not under the permissible limits of WHO. The values of arsenic at all the sites were under the permissible limits of WHO.
KEYWORDS: Groundwater, Sanitary landfill, Open Dumping, Physicochemical parameter, Heavy metals.

I. INTRODUCTION

Water is the most important in shaping the land and regulating the climate. It is one of the most important compounds that profoundly influence life.Groundwater is used for domestic and industrial water supply and also for irrigation purposes in all over the world (Dohare*et al.*,2014). The quality of groundwater is of paramount importance. In recent years, the risk of groundwater pollution has become one of the most important environmental concerns. The improper Municipal solid waste (MSW) management is the major factor for deteriorating groundwater quality around landfill sites (Deswal and Laura., 2014; Saini *et al.*,2018; Deswal and Laura., 2018). In most of the developing countries, MSW is being dumped on land without adopting any acceptable sanitary landfilling practices such as engineered liners, leachate interception and collection system etc. without such, leachate that seeps from a landfill usually percolates through the soil and reaches the groundwater (Mor et al., 2006; Deswal and Laura, 2018).This leads to groundwater contamination almost immediately. The leachate generated in such a way has a high concentration of toxic substances and pathogenic microorganisms. The concentration of these elements and compounds in leachate and the groundwater surrounding microorganisms the composition of wastes dumped (Alker et al., 1995; Deswal et al., 2014). The impact of landfill leachate on surface and groundwater has given rise to a number of studies in recent years and gained major importance due to the drastic increase in population. By studying different literature papers major parameters that are used to determine the groundwater quality includes electrical conductivity, pH, total dissolved solids (TDS), dissolved oxygen (DO), alkalinity, hardness, chloride, Sulphate (SO_4^{2-}), Nitrate (NO_3^-), fluoride (F^-), and Phosphate (PO_4^{3-}). They were proved to be tracers of groundwater contamination.

Table no 1: List of various physicochemical parameters and their impact

Physicochemical parameter	Impact	References
TDS	Kidney and heart diseases,Laxative effects, Constipation, gastrointestinal irritation	Sasikaran*et al.,* (2012); WHO (1997)
Total hardness	Unpleasant taste, heart disease, kidney stone formation	Vincent (2016)
Total alkalinity	Unpleasant taste	Mor*et al., (*2006)
Nitrate	Blue baby syndrome	Chavan*et al.,* (2013)
Sulphate	Imparts Bitter or medicinal taste to water, catharsis,dehydration and gastrointestinal irritation	Bertram *et al.,* (1996);Hauser *et al.,*(2001)
Fluoride	Dental and skeletal fluorosis,teeth mottling	Malviya*et al.,*(2017)
Chloride	High blood pressure(hypertension), the risk for stroke, osteoporosis, renal stones and asthma	McCarthy *et al.,* (2004); Ramesh *et al.,* (2012)
Sodium	Heart failure	McCarthy *et al.,* (2004)

Table no 2: List of various Heavy metals and their impact

Heavy metal	Impact	References
Iron	Cellular damage, mutation and malignant transformations	Grazuleviciene*et al.,* (2009)
Zinc	Vomiting, dehydration, drowsiness	Prasad *et al.,*(1976); Athar *et al.,*(1995)
Manganese	Parkinson's disease	Ghosh *et al.,*(2020)
Cadmium	Nausea, Vomiting, Itai-Itai disease, Abdominal cramps, Muscular weakness	Lalor*et al.,*(2008);Duruibe*et al.,*(2007)
Nickel	Asthma, Heart disorder, Cancer, skin allergies	Prazak*et al.,*(2003)
Lead	Fatigue, Anaemia, High B.P, Gastro-intestinal problems, Joint pain	Odum(2000)
Copper	Wilsons disease,Liver and kidney damage	Athar *et al.,* (1995)
Arsenic	Black foot disease	Ghosh *et al.,(*2020)

II. METHODOLOGY

This study was performed to know the scenario of important water contaminants presence in groundwater of India. The data was downloaded from Google Scholar, ResearchGate, Springer, Elsevier, Semantic Scholar, Scopus etc. and analyse thoroughly to present uranium occurrence in groundwater of Haryana systematically. More than eighty articles including reports and reviews were reviewed to do this work and data was tabulated.

III. RESULT AND DISCUSSION

Table 3 shows the various physicochemical parameters of groundwater around waste disposal sites in India.Out of the 40 sites studied in India, only 8 were sanitary landfill and the remaining were open dumps. The results were compared with the permissible limits of WHO and the values exceeding the permissible limits of WHO were highlighted. The pH values,Potassium,Phosphate,DO and COD values at all the sites were found to be under the permissible limit. It was found that Sulphate and Fluoride values at 15% sites were exceeding the permissible limits as prescribed by WHO. Total Alkalinity, Total hardness,TDS, EC and sodium at 25%,52.5%,50%,42.5%,20% sites respectively were not under the permissible limits as prescribed by WHO.The concentration of Magnesium and nitrate at 17.7% and Sulphate and Fluoride at 15% siteswere higher than the prescribed limit.At seven sites more than five physicochemical parameters were found to be higher than the permissible limit of WHO. It indicates that water at these sites was highly contaminated. These sites were Jaipur, Kanchipuram, Hyderabad, Trichy, and Pirana.

Table 4 Shows the Heavy metals in groundwater around waste disposal sites in India.The heavy metal test was not performed for groundwater samples at 17 sites.Test for more than 3 heavy metals was performed at ten sites. The concentration of manganese,cadmium and chromium at 17.3% sites were exceeding the WHO standards.At 8.6% sites,the values of zinc and lead were higher. The concentration of iron, copper and nickel at

43.4%,13.04% and 4.3% sites respectively exceeds the permissible limits of WHO.At Satna (Bihar) Heavy metal test for five heavy metals was performed but the results for all the heavy metal was not detectable. Heavy metal contamination was highest in groundwater samples of Dhapa and Hyderabad. It means the water at both these sites is highly polluted and not fit for drinking purpose. From the various studies, it can be seen that most of the researchers performed the heavy metal test for Iron. At 11 sites the values of Iron were exceeding the permissible limits of WHO. At Trichy (Tamilnadu) Sanitary landfill is used for the disposal of waste. The values of chromium were above the permissible limits of WHO. It shows the poor management of the Sanitary landfill sites.

Thus it can be concluded that the groundwater is being polluted. At many sites, the water was so badly impaired that it cannot be used for household purposes. Groundwater was highly contaminated at Hyderabad (Telangana) where values of six physicochemical and five heavy metals were higher than the permissible limits of WHO.

More contamination in groundwater is found to be near open dumps. However, groundwater around sanitary landfill sites was also contaminated. The reason might be poor management of the sanitary landfill.The papers reviewed shows groundwater contamination due to open dumping and sanitary landfill sites. It was observed that groundwater contamination was higher around the open dumping sites & less near sanitary landfill sites. Another thing observed was that the contamination decreases with an increase in depth and distance from the waste management sites. Research studies included the analysis of the physicochemical parameters as well as the heavy metals.

Literature Review

The following tables explain different studies made to determine the physicochemical properties of groundwater around different landfill sites.

Table no 3: Physicochemical parameters of groundwater around sanitary landfill sites in India

Location	pH	EC	TDS	TH	TA	Ca	Mg	Na	K	Cl	SO_4^{2-}	F	NO_3^{2-}	PO_4^{3-}	DO	BOD	COD	NH_4	Dumpsite type	Authors
Unit		µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		
Trichy (Tamilnadu)	6.6-8.1	986-**2990**	658-**1913.6**	348-**2140**	-	100-**944**	96-**354**	112-**560**	0-24.2	114-347	7-49	0.1-0.23	-	-	-	-	-	-	Sanitary landfill	Senthamizhselvanet al., (2019)
Madurai (Tamilnadu)	-	-	798-**3218**	300-**1680**	272-424	-	-	-	-	-	-	1.2-**2.54**	1.2-17.9	0.15-2.4	-	-	-	-	Open dumping	Ravi *et al.*,(2019)
Guntur (Andhra Pradesh)	7.2-7.8	0.2-0.5	120-427	-	14-22	-	-	-	-	-	-	0.03-0.15	-	-	0.2-0.5	-	-	-	Open dumping	Chilukuriet al., (2019)
Kanuru (Andhra pradesh)	7.2-7.8	0.2-0.5	116-342	7-83	12-28	-	-	-	-	269-874	-	0.01-0.15	-	-	0.1-0.8	-	16-29	-	Open Dumping	Chandra et al., (2019)
Dubagga (Uttar pradesh)	7.2-7.6	492-735	339-624	212-317	215-312	21-65	15-52	12-49	_	15-35	43-44	0.6-1.2	2-2.2	_	_	_	_	_	Open Dumping	Ali *et al.*, (2018)
Pirana (Gujrat)	7.3-7.9	-	820-**2350.6**	230-**810**	-	120-**490**	104-**320**	_	_	255-**760**	68-374.1	-	**120-173**	_	_	_	_	_	Sanitary landfill	Chopdaet al., (2018)
Raipur (Chattisgarh)	6.3-8.3	235-**2360**	240-**5470**	270-**1480**	340-**1770**	_	_	_	_	205-**657**	_	_	_	_	_	_	10.2-56.6	_	Open Dumping	Sharma et al., (2018)
Jaipur (Rajasthan)	7.05-8.4	850-**4527**	544-**2897**	90-**1190**	_	16-**340**	12-141	85-**755**	1-11	50-**1115**	0-425	0.5-**3.0**	_	_	_	_	_	_	Open Dumping	Saini *et al.*,(2018)
Nagpur (Maharashtra)	8.1-8.4	_	_	_	_	_	_	_	_	_	_	_	13.29-37.21	_	_	2.8-3.8	_	_	Open Dumping	Gillurkaret al.,(2017)
Mayiladuthurai,Nagapattinam (TamilNadu)	_	_	_	_		_	_	_	_	_	25-45	0.4-0.6	3-7	0-0.62	_	_	18-24	_	Open Dumping	Sangeethaet. al.,(2017)
Perungudi (Tamilnadu)	7.1-8.9	**1025-77900**	665-**53000**	290-**21000**	_	48-2400	19-3888	_	_	330-**37000**	60-**14000**	0.1-0.8	_	0-015-1.0	0.2-3.15			0.03-5.6	Open dumping	Mageswariet al., (2017)
Chennai (TamilNadu)	7.3-7.4	**1976-2720**	1264-**1700**	394-432		91.4-185	40-69	_	_	177-205	_	_	_	_	_	_	_	_	Sanitary landfill	Riya *et al.*,(2017)
Srikakulam (Andhra Pradesh)	6.9-7.5	648-**3340**	421-**2171**	232-**810**	208-480	38-91	47-174	_	_	100-**700**	_	0.62-0.92	10.4-**65**	_	_	_	_	_	Open Dumping	Srigirisettyet al.,(2017)
Varanasi (Uttar Pradesh)	5.6-7.4	0.56-1.67	331-1140	230-**640**	230-**630**	10.6-77.4	_	6-137	0.3-41.6	39-205	_	0.1-1.1	16-**252**	_	3.5-7.8	_	21-360	_	Open Dumping	Mishra *et al.*, (2017)
Pipariya (Madhya Pradesh)	7.7-7.9	885-910	887-907	375-394	134-142	146-153	143-**151**	_	_	244-253	99-129	0.08-0.12	0-4.1	9.5-10.2	2.4-3.0	_	_	_	Sanitary landfill	Malviyaet al., (2017)
Hyderabad (Telangana)	6.7-7.4	196-**1930**	778-**3070**	_	_	53.78-191.97	18.01-**93.79**	65.41-164.99	0.12-14.54	53.28-**665.9**	13.64-167.15	0.37-**2.64**	0.25-**439.21**	_	_	_	_	_	Open Dumping	Kurakalvaet al.,(2016)
Kanchipuram (Tamil Nadu)	6.7-8.5	**1225-9120**	812-**6230**	269-**1730**	225-**825**	48-**364**	21-213	_	_	145-2115	110-**795**	0.3-1.9	20-51	0-4.5	_	_	_	_	Open Dumping	Kumar *et al.*, (2016)
Thoothukudi (Tamilnadu)	7.4-7.8	**1410-7118**	100-1270	105.4-**544.9**	454.7-**1417.7**	_	_	_	_	77.2-365	_	_	_	_	_	_	_	_	Open dumping	Vincent.(2016)
Dhapa (West Bengal)	7.8-8.2	**9557-60857**	6690-42600	_	_	_	_	_	_	2103-18697	876-2614	_	110-776	27-197	_	2497-5493	4070-9128	_	Open Dumping	Maitiet al., (2015)
Dhanbad (Jharkhand)	6.6-7.8	0.17-1.3	124-906	296-**536.6**	84.3-326.6	188-**330**	31.6-310	4.8-61.2	0.1-4.2	48.5-113.9	25.2-125.3	_	3.7-14.6	_	_	_	2.0-192	_	Open Dumping	Pandeet al., (2015)
Kodungaiyar, Chennai (Tamilnadu)	6.2-6.92	**1283-2574**	1015-**2225**	290-**820**	_	36-160	32-135	73-**542**	7-83	50-**638**	86-274	0.13-0.97	0.16-1.22	_	_	_	_	_	Open Dumping	Eshanthinet al., (2015)
Rewa (Madhya Pradesh)	7.02-7.85	571-959	546-907	150-307	76-198	102-**265**	33-68	_	_	121-285	2.9-171	0.01-1.1	**0-54**	0-0.05	3.9-6.29	1.1-3.6	2.8-**23.6**	ND-4.3	Sanitary landfill	Kashyap (2015)
Thuraipakkam	5.5-	_	1138-	232-	112-	51-	19-96	_	_	168-	_	_	_	_	_	_	_	_	Open	Arafathet al.,

(Tamilnadu)	7.7		**5537**	**1500**	**768**	**440**				**2400**									Dumping	(2014)
Mavvalipura, Banglore (Tamilnadu)	7.6-8.8	533-917	320-641.9	205-368	217-255	132-**223**	73-145	–	–	–	–	0.4-0.6	–	–	0.3-2.6	0.4-3.1	–	–	Open Dumping	Ramaiah*et al.*,(2014)
Dehradun (Uttrakhand)	7.0-8.0	210-310	128-199	230-330	180-310	–	–	–	–	116-300	–	–	–	–	–	–	–	–	Open Dumping	Gawsia*et al.*,(2014)
Kolhapur (Maharashtra)	6.5-7.1	–	165-**1832**	212-422	–	66-130	15-80	–	–	–	–	–	–	–	–	–	–	–	Sanitary Landfill	Chavan*et al.*,(2014)
Agra (Uttar Pradesh)	6.4-8.1	–	739-**1720**	347-**603**	342-**587**	–	–	–	–	347-603	–	–	–	–	–	–	–	–	Open Dumping	Ashfaq*et al.*,(2014)
Satna (Bihar)	7.2-7.8	472-728	587-760	397-**567**	87-164	118-**268**	74-128	–	–	132-205	–	0.1-0.8	1.0-3.4	0.0-8.2	5.1-5.8	–	2.4-3.8	–	Open Dumping	Pandey *et al.*,(2013)
Guwahati (Assam)	7.1-7.9	218.2-310.5	109-146.2	66-130	50-130	–	–	–	–	–	–	–	–	–	1.6-3.6	–	–	–	Open Dumping	Gohain*et al.*,(2013)
Turmuri (Karnatka)	6.0-8.04	–	61-185	20-80	–	–	–	–	–	–	–	–	6.8-**71.16**	–	–	–	–	–	Open Dumping	Patil*et al.*,(2013)
Chenai (Tamilnadu)	6.1-8.1	**1038-4129**	–	726.6-**2890.3**	–	14-198	34-220	–	–	519.8-**5318.3**	–	–	–	–	–	–	–	–	Open Dumping	Shenbgarani (2013)
Jabalpur (Madhya Pradesh)	7.02-7.85	571-959	546-907	150-307	76-198	102-**265**	42-68	–	–	121-285	2.9-171	0.01-1.1	0-54	0-0.05	4.2-5.7	1.4-3.8	2.9-34.2	0-4.3	Open Dumping	Bundela*et al.*,(2012)
Jaipur (Rajasthan)	7.1-7.8	1.34-3.5	610.4-**1828.4**	130-**600**	–	60-**320**	60-**280**	–	–	288.4-**1038.2**	–	**2.4-3.2**	0.4-1.6	0-1.2	–	–	–	–	Open Dumping	Gautam*et al.*,(2011)
Erode City (Tamilnadu)	7.1-8.2	410-**3830**	267-**2345**	170-**1070**	210-**675**	28-188	5-**209**	0-**437**	4-76	–	12-300	0.14-**15**	0-47	–	–	–	–	–	Open Dumping	Rajkumar*et al.*,(2010)
Jalgaon (Maharashtra)	7.1-8.0	386-**2827**	80-**1760**	170-**870**	160-**647.4**	27.25-114.6	20.95-142.3	37.61-**372.3**	0.402-4.626	16.9-447.9	15.73-89.89	–	0.041-1.271	0.155-0.233	2.2-8.3	–	–	–	Open Dumping	Patil*et al.*, 2010
Ahemdabad (Gujarat)	7-7.2	**1160-1485**	769-949	–	–	**328-383**	68-98	20.4-27	1.53-43	110-192	76.8-170.5	–	32-**73.5**	0.18-0.65	–	–	–	–	Sanitary Landfill	Singh *et al.*, (2008)
Bhalsawa (Delhi)	–	–	–	–	–	–	–	–	–	136.3-**1174.2**	–	–	–	–	–	–	–	–	Sanitary Landfill	Jhamnani*et al.*,(2009)
Pallavaram (Tamilnadu)	5.2-6.5	**2950-3290**	**1622-1809**	450-**669**	40-260	107-169	22.5-60.1	**449.8-482.2**	8-22.4	**729-877**	351-**487**		22.3-26.3	0.11-0.16					Open dumping	Raman *et al.*,(2008)
Panipat (Haryana)	6.6-7.5	90-328	600-**2100**	152-**520**	245-**1054**	6.0-95	6.0-93	57-**560**	5.0-22	–	17-**786**	0.24-**9.27**	–	–	–	–	–	–	Open Dumping	Bishnoi*et al.*,(2007)
Gazipur (Delhi)	7.02-7.85	617-**3620**	302-**2208**	–	230-**734**	43-**477**	**ND-220**	22-**313**	6-56	28-**737**	12-**1096**	0.37-1.13	ND-0.56	ND-0.06	–	–	2-17	ND-4.3	Open dumping	Mor*et al.*,(2006)

Table no 4: Heavy metals in groundwater around sanitary landfill sites in India

Location	Fe	Zn	Cu	Mn	Pb	Cd	Cr	As	Ni	Dumpsite type	Author
Unit	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		
Madurai (Tamilnadu)	–	0.002-0.028	–	–	–	–	–	–	–	Open dumping	Ravi *et al.*,(2019)
Trichy (Tamilnadu)	–	0.01-0.36	0.07-0.12	–	–	–	0.01-**0.4**	–	–	Sanitary landfill	Senthamizhselvan*et al.*,(2019)
Guntur (Andhra Pradesh)	–	–	–	–	–	–	–	–	–	Open dumping	Chilukuri*et al.*, (2019)
Kanuru (Andhra Pradesh)	–	–	–	–	–	–	–	–	–	Open Dumping	Chandra *et al.*,(2019)
Pirana (Gujrat)	–	–	–	–	–	–	–	–	–	Sanitary landfill	Chopda*et al.*,(2018)
Dubagga (Uttar pradesh)	–	–	–	–	–	–	–	–	–	Open Dumping	Ali *et al.*,(2018)
Raipur (Chattisgarh)	–	–	–	–	–	–	–	–	–	Open Dumping	Sharma *et al.*, *(2018)*
Jaipur (Rajasthan)	–	–	–	–	–	–	–	–	–	Open Dumping	Saini *et al.*,(2018)
Nagpur (Maharashtra)	–	–	–	–	–	–	–	–	–	Open Dumping	Gillurkar*et al.*,(2017)
Mayiladuthurai,nagapattinam (TamilNadu)	0.0-**2.6**	–	–	–	–	–	–	–	–	Open Dumping	Sangeetha*et al.*,(2017)
Perungudi (Tamilnadu)	0.1-2.5	–	–	–	–	–	–	–	–	Open Dumping	Mageswari*et al.*,(2017)
Chennai (Tamilnadu)	0.06-**1.106**	–	–	–	0.8-0.98	–	–	–	–	Sanitary landfill	Riya *et al.*,(2017)
Srikakulam (Andhra Pradesh)	0.01-0.04	–	–	–	–	–	–	–	–	Open Dumping	Srigirisetty*et al.*,(2017)
Varanasi (Uttar Pradesh)	0.01-**3.66**	ND	ND	–	–	ND	ND	ND	ND	Open Dumping	Mishra *et al.*,(2017)
Pipariya (Madhya Pradesh)	0.1-0.2	–	–	–	–	–	–	–	–	Sanitary landfill	Malviya*et al.*,(2017)
Hyderabad (Telangana)	0.37-**2.9**	1.49-**49.59**	0.61-**167.15**	**1.04-1072**	0.19-**1.32**	0-**0.09**	**24-28**	0.04-036	–	Open Dumping	Kurakalva*et al.*,(2016)
Kanchipuram (Tamil Nadu)	0.0-**69.3**	–	–	–	–	–	–	–	–	Open Dumping	Kumar *et al.*,(2016)
Thoothukudi (Tamilnadu)	–	–	–	–	–	–	–	–	–	Open dumping	Vincent.(2016)
Dhapa (West Bengal)	**4.320-11250**		**0.140-0380**	–		**0.018-0030**	**1.47-10.43**	–	–	Open Dumping	Maiti*et al.*,(2015)
Kodungaiyar, Chennai (Tamilnadu)	–	–	–	–	–	–	–	–	–	Open Dumping	Eshanthini*et al.*,(2015)
Dhanbad (Jharkhand)	0.02-0.4	0.09-1.14	0-0.04	0.004-**0.79**	0-0.01	0.0004-**004**	–	–	0.005-0011	Open Dumping	Pande*et al.*,(2015)
Rewa (Madhya Pradesh)	ND-0.2	–	–	–	–	–	–	–	–	Sanitary landfill	Kashyap (2015)
Thuraipakkam (Tamilnadu)	–	–	–	–	–	–	–	–	–	Open Dumping	Arafath*et al.*, (2014)
Mavvalipura, Banglore (Tamilnadu)	0.01-0.04	–	–	–	–	–	–	–	–	Open Dumping	Ramaiah*et al.*,(2014)
Hassan city (Karnatka)	–	–	–	–	–	–	–	–	–	Open Dumping	Patil*et al.*,(2014)
Dehradun (Uttrakhand)	–	–	–	–	–	–	–	–	–	Open Dumping	Gawsia*et al.*,(2014)
Kolhapur (Maharashtra)	–	–	–	–	–	–	–	–	–	Sanitary Landfill	Chavan*et al.*,(2014)
Agra (Uttar padesh)	–	–	–	–	–	–	–	–	–	Open Dumping	Ashfaq*et al.*,(2014)
Satna (Bihar)	ND	ND	ND	–	ND	–	–	–	ND	Open Dumping	Pandey *et al.*,(2013)
Guwahati (Assam)	–	0.01-0.4	0.001-0.1	**1.02-2.41**	–	–	–	–	0.006-0379	Open Dumping	Gohain*et al.*,(2013)
Turmuri (Karnatka)	–	–	–	–	0.0002-00033	–	–	–	–	Open Dumping	Patil*et al.*,(2013)
Chennai (Tamilnadu)	0.01-1.5	0.01-0.12	0.016-0047	–	0.25-0.45	0.0-0.016	0.001-0067	–	0.09-0.35	Open Dumping	Shenbgarani (2013)
Jabalpur (Madhya Pradesh)	ND-0.3	–	–	–	–	–	–	–	–	Open Dumping	Bundela*et al.*,(2012)
Jaipur (Rajasthan)	NT	NT-1.15	NT-0.02	–	NT	NT	–	–	–	Open Dumping	Gautam*et al.*,(2011)
Erode City	–	–	–	–	–	–	–	–	–	Open Dumping	Rajkumar*et al.*,(2010)

(Tamilnadu)											
Jalgaon (Maharashtra)	–	–	–	–	–	–	–	–	–	Open Dumping	Patil*et al.*, 2010
Bhalsawa (Delhi)	0.6-**7.0**	0.02-3.3	0.01-0.1	–	–	–	–	–	0.1-0.4	Sanitary Landfill	Jhamnani*et al.*, (2009)
Ahemdabad (Gujarat)	**2.0-195**	**8-90**	**6-32**	**2-17**	**3-42**	**1-5**	**2-30**	–	**2-7**	Sanitary Landfill	Singh *et al.*, (2008)
Pallavaram (Tamilnadu)	0.24 -**2.5**	0.01- 0.3	–	–	–	–	–	–	–	Open dumping	Raman *et al.*, (2008)
Panipat (Haryana)	–	–	–	–	–	–	–	–	–	Open Dumping	Bishnoi*et al.*,(2007)
Gazipur (Delhi)	0.04-**2.4**	0-0.8	–	–	–	–	–	–	–	Open dumping	Mor*et al.*, (2006)

Table no 5: Physicochemical parameters of groundwater around sanitary landfill sites of the world

Location	pH	EC	TDS	TH	TA	Ca	Mg	Na	K	Cl	SO_4^{2-}	F	NO_3^{2-}	PO_4^{2-}	DO	BOD	COD	NH_4	Dumpsite type	Authors
Unit		µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		
Ekiti (Southwestern Nigeria)	6.4-7.4	187-647	116-413	48-81	–	–	–	–	–	34.4-57.8	6.2-12	–	2-3.6	–	6.4-8.8	4.8-**9.4**	–	–	Open Dumping	Okunade*et al.*,(2019)
Hamedan Landfill (Iran)	6.90-7.80	–	505-8434.00	–	–	–	–	–	–	–	–	–	5.35-**240**	0.03-0.54	–	0.00-54.0	1.00-72.00	–	Open Dumping	Navid*et al.*,(2018)
Revdalen Landfill (Norway)	6.63-7.81	0.95-1.31	124-906	296-**536.66**	84.3-326.66	188-**330**	31.66-310	4.8-61.20	0.10-4.22	48.5-113.96	25.2-125.39	–	3.7-14.6	–	–	–	2-192	–	Open Dumping	Abiriga*et al.*,(2017)
Multan (Pakistan)	7.5-8.2	321-**1040**	214.2-**655.2**	66-264	92-296	11.2-52.8	8.1-32.6	–	–	11-77	–	–	–	–	–	–	–	–	Open Dumping	Murtaza*et al.*,(2017)
Soluos Dumpsite (Nigeria)	4.6-7.9	0.10-2.69	30.7-**1535**	11.9-204	10.7-36.6	8.57-178	4.11-19.0	21.1-424	6.29-44.3	17.2-371	2.92-228	–	0.15-3.91	0.18-0.94	–	–	–	–	Sanitary Landfill	Abdulrafiu*et al.*,(2017)
Lahore (Pakistan)	7.6-8.7	288-**1022**	181-**644**	66-434	138-480	11.2-85	9.1-53	–	–	6-104	–	–	–	–	–	–	–	–	Sanitary landfill	Sohail *et al.*,(2017)
Ede (Nigeria)	6-7.1	125-326	–	120-174	78-166	30.4-40.8	9-17.10	–	–	–	2-18	–	0.05-3.6	–	2.1-5.2	–	–	–	Open Dumping	Adebara*et al.*, (2016)
Osogbo (Nigeria)	5.90-7.40	–	144-212	142-249	–	84-124	46-92	–	–	7.50-17.50	–	–	–	–	–	–	–	–	Sanitary Landfill	Adebara*et al.*,(2016)
Maiduguri (Nigeria)	7.3-8.3	165-795	90-643	112-364	-	29.7-46.8	-	-	-	22-148	-	-	0.31-6.8	-	-	10-14	-	-	Open Dumping	Usman *et al.*, (2016)
Qom (Iran)	6.3-7.7	663-**14850**	1100-**5841**	–	–	11.5-25	5.4-20.1	33-112.1	9-37	19.2-66.7	18.4-110.1	–	21.3-34.1	0.2-8.8	–	–	–	–	Sanitary Landfill	Ardani*et al.*, (2015)
Okeafa landfill, Lagos (Nigeria)	6.2-6.5	182-**1147**	124-736	37.8-126	18.8-44.4	–	–	–	–	19.7-128.2	0.02-0.08	–	0.05-0.07	0.12-0.22	3.22-6.67	45.2-89.1	–	–	Sanitary Landfill	Oluseyi*et al.*,(2014)
Alexandria (Egypt)	6.2-9	–	–	414-**528**	125-313	124-169	61-108	–	–	338-**754**	192-352	0.7-**2.1**	39-**78**	–	–	–	–	–	Open Dumping	Magda *et al.*, (2014)
Lagos , (Nigeria)	5.1-7.0	201-**1094**	139-567	41.4-165.6	0-133.5	–	–	–	–	24.6-270.9	0.02-0.09	–	0.04-1.07	0.18-1.88	4.85-8.47	40.5-74.8	–	–	Sanitary Landfill	Oluseyi*et al.*,(2014)
Effurun (Nigeria)	5.2-6.8	20.24-**1200**	9.67-765.3	–	–	11.3-38.0	0.10-1.50	10. 0-65.40	5.79-32.2	8.90-225	0-24.3	–	0.08-**56.0**	0-8.25	–	6.50-16.40	0-35	0-0.90	Open Dumping	Ohwoghere*et al.*,(2013)
Osun State (Nigeria)	7.5-10.8	70-364	49-284	–	–	3.95-65.12	0.73-17.28	3.45-27.37	1.04-24.41	122-**720**	0-7.413	–	0.641-1.683	–	–	–	–	–	Sanitary Landfill	Oyelami*et al.*,(2013)
Aarda dumpsite (Nigeria)	6.9-7.9	600-**1333**	500-900	48.75-71.89	–	–	5.9-24.0	9.45-45.87	10.5-75.3	5.34-60.65	0.75-9.75	–	3.56-**70.98**	–	41.65-101.5	0.01-5.75	0.22-5.14	–	Sanitary Landfill	Olafisoye*et al.*,(2013)
Gohagoda (Srilanka)	3.2-7.8	–	–	–	–	–	–	–	–	–	–	3-110	–	2.3-25.3	0.07-0.72	–	–	–	Sanitary Landfill	Nirmala*et al.*,(2013)
MehmoodBoti Landfill, Lahore (Pakistan)	7.0-8.2	816-**2280**	522-**3341**	**700-3100**	320-**1000**	80-**280**	24-**586**	44-115	0.9-100	14-**638**	98-166	–	–	0.1-16.9	–	–	–	–	Open Dumping	Satyavani*et al.*,(2012)
Bukit Tagar Sanitary Landfill,Selengor (Malaysia)	4.3-6.8	35-91	–	–	–	**1257-4045**	0.358-4.25	**2032-2256**	0.736-**1813**	1.4-4.8	2.0-8.0	–	0.2-1.3	–	–	–	2.0-6.0	–	Sanitary Landfill	Taha*et al.*, (2011)
Akure (Nigeria)	5.6-6.8	–	18-342	136-140	–	69-83	–	–	–	17-122	–	–	30-**61**		0.9-2.4	–	–	–	Sanitary Landfill	Christopher *et al.*, (2011)
Ifo, South western (Nigeria)	4.6-7.3	–	181-901.5	23.4-334.04	10.01-80.1	–	–	–	–	–	–	–	–	–	–	–	–	–	Sanitary landfill	Majolagbe*et al.*, (2011)
Isolo, South western (Nigeria)	4.3-6.6	0.29-2.45	92-512	44.2-210.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Sanitary landfill	Majolagbe*et al.*, (2011)

Table no 6: Heavy metals in groundwater around sanitary landfill sites in World

Location	Fe (mg/l)	Zn (mg/l)	Cu (mg/l)	Mn (mg/l)	Pb (mg/l)	Cd (mg/l)	Cr (mg/l)	As (mg/l)	Ni (mg/l)	Dumpsite type	Author
Ekiti(Southwestern Nigeria)	0.2-**0.5**	–	–	–	–	–	–	–	–	Open Dumping	Okunade*et al., (2019)*
Hamedan Landfill (Iran)	–	–	–	–	–	–	–	–	–	Open Dumping	Navid*et al., (2018)*
Revdalen Landfill(Norway)	**0-90.8**	–	–	**0.68-35.00**	**0-852**	**0-9.5**	**0-37**	–	–	Open Dumping	Abiriga*et al., (2017)*
Lahore (Pakistan)	–	–	–	–	–	–	–	–	–	Sanitary landfill	Sohail *et al.*, (2017)
Multan (Pakistan)	0-0.02	–	–	–	–	–	–	1-143	–	Open Dumping	Murtaza*et al.*, (2017)
Soluos Dumpsite (Nigeria)	**1.24-36.1**	0.14-2.37	0.03-0.21	–	0.00-0.001	0.001-0.02	–	–	–	Sanitary Landfill	Abdulrafiu*et al., (2017)*
Maiduguri (Nigeria)	0.4-1.2	0.04-0.25	ND-0.050	ND-0.075	ND	–	ND-0.865	–	–	Open Dumping	Usman *et al.*, (2016)
Ede (Nigeria)	0.01-0.07	0.001-0.016	0.00-0.003	0.00-0.003	–	–	0.00-**0.08**	–	–	Open Dumping	Adebara*et al.*, (2016)
Osogbo (Nigeria)	–	–	–	–	–	–	–	–	–	Sanitary landfill	Adebara*et al., (2016)*
Qom (Iran)	–	–	–	–	–	–	–	–	–	Sanitary Landfill	Ardani*et al.*, (2015)
OkeafaDumpsite,Lagos (Nigeria)	0.102-0.129	0.049-0.086	0.009-0.012	0.010-0.016	–	–	0.001-0.009	–	0.003-0.009	Sanitary Landfill	Salami *et al., (2014)*
Okeafa landfill, Lagos (Nigeria)	–	–	–	–	–	–	–	–	–	Sanitary landfill	Oluseyi*et al., (2014)*
Alexandria landfill (Egypt)	**0.44-5.90**	0.001-0.343	0.004-0.067	0.182-**0.673**	0.004-0.009	0.001-0.061	**0.006-0.158**	0.01-0.152	–	Open Dumping	Magda *et al., (2014)*
Lagos (Nigeria)	–	–	–	–	–	–	–	–	–	Sanitary landfill	Oluseyi*et al., (2014)*
Effurun (Nigeria)	0.01-1.90	–	–	–	–	–	–	–	–	Open Dumping	Ohwoghere*et al.*,(2013)
Osun State (Nigeria)	0-1.36	0-0.41	ND	0-0.57	ND	ND	ND	–	–	Sanitary Landfill	Oyelami*et al.*,(2013)
Gohagoda (Srilanka)	**1.2-17.6**	0.11-0.58	0.04-**0.44**	**1.4-29.2**	–	–	0.01-**0.2**	–	0.01-0.05	Sanitary Landfill	Nirmala*et al.*,(2013)
Aarda dumpsite (Nigeria)	**0.5-4.7**	1.3-2.5	**0.5-0.90**	–	0.0-0.75	–	–	–	–	Sanitary landfill	Olafisoye*et al., (2013)*
MehmoodBoti Landfill, Lahore (Pakistan)	–	–	–	–	–	–	–	–	–	Open Dumping	Satyavani*et al., (2012)*
Ifo, South western (Nigeria)	–	–	–	–	–	–	–	–	–	Sanitary landfill	Majolagbe*et al.*,(2011)
Isolo, Southwestern (Nigeria)	–	–	–	–	–	–	–	–	–	Sanitary landfill	Majolagbe*et al.*,(2011)
Bukit Tagar Sanitary Landfill,Selengor (Malaysia)	0.148-**0.559**	0.036-0.074	0.002-0.026	0.11-0.087	0.002-0.013	0.001-0.015	–	0.005	–	Sanitary landfill	Taha*et al., (2011)*
Akure (Nigeria)	0.9-1.2	ND-2.3	ND	ND	ND-1.2	–	ND-0.25	–	–	Sanitary Landfill	Christopher *et al.*, (2011)

IV. CONCLUSION

This review paper included the analysis of groundwater samples around 63 municipal solid waste dumping sites, from India as well as from other countries. The sites in these studies included both open dumps as well as sanitary landfills. Most of the papers reviewed are from developing countries. It is because developed countries followthe most effective approach to solid waste management. On the other hand, there is uncontrolled dumping of waste and waste burning practices are being done in developing countries causing serious health and environmental problems.

It was found that EC,TDS and Total Hardness at 38% sites were exceeding the permissible limits as prescribed by WHO. Magnesium, Sodium and Fluoride at 12.6% sites were not under the permissible limits of WHO. The values of pH, Potassium, BOD and COD were higher than the permissible limits at only 1.5% sites. Total Alkalinity, Calcium, Chloride, Sulphate, Fluoride and Nitrate at 15.8%,25.3%,26.9%,9.5%,19% sites were not under the permissible limits as prescribed by WHO. However, the values of Ammonia, Phosphate and BOD at 100% sites were under the permissible limits of WHO. The concentrations of Iron,Zinc, Copper, Manganese,Lead,Cadmium, Chromium and Nickel at 28.5%,3.1%,7.9%,11.1%,4.7%,7.9%,12.6% and 1.5% sites were not under the permissible limits of WHO. The values of arsenic at all the sites were under the permissible limits of WHO.

It is recommended that no human settlement should be allowed up to a minimum distance of 500m from MSW dumping sites. It can be concluded that the poor practices of waste disposal are beingcarried out at Municipal Solid Waste Dumping site in various states and the absence of the leachate collection system has a great impact on the groundwater quality. The collected solid waste must be segregated, treated and disposed of in an environmentally acceptable manner. It is suggested that the concerned authorities should take serious steps for the control of groundwater pollution by providing a base of cement concrete to insure for the safety of local peoples, environment and public health. The quality of the groundwater was found to improve with the increase in depth and distance of the water resources from the landfill site.Solid waste management rule 2016 should be strictly followed to prevent Groundwater pollution caused by solid waste disposal sites. Sanitary landfill should be used in place of open dumping and this sanitary landfill should have proper bottom liners and a leachate collection system. It is advised to monitor the groundwater on a regular basis.

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Table no 7: Drinking Water Quality Standards as recommended by BIS AND WHO

PARAMETER	UNIT	BIS STANDARDS	WHO STANDARDS
pH	-	6.5-8.5	9.2
EC	µS/cm	-	1000
TDS	mg/L	500-2000	500-1500
TURBIDITY	NTU	1.0-5.0	5.0
TH	mg/L	200-600	500
T.A	mg/L	200-600	500
TSS	mg/L	500	-
Na^+	mg/L	-	200
K^+	mg/L	-	200
Ca^{2+}	mg/L	75-200	200

Mg^{2+}	mg/L	30-100	150
Cl^-	mg/L	250-1000	600
NO_3^-	mg/L	45	45
SO_4^{2-}	mg/L	200-400	400
F^-	mg/L	1.0-1.5	1.5
Cr	mg/L	0.05	0.05
Mn	mg/L	0.1-0.3	0.2
Ni	mg/L	0.02	<1
Fe	mg/L	0.3	0.3
Pb	mg/L	0.01	1.0
Zn	mg/L	5-15	6
Cu	mg/L	0.05-1.5	0.1
Cd	mg/L	0.003	0.01
As	mg/L	0.01-0.05	-
NH_4^+	mg/L	0.5	-
DO	mg/L	-	-
BOD	mg/L	-	2.0-5.0
COD	mg/L	-	10
uranium	ppb	60	30

Shikha Kumari, et. al. " Physicochemical properties of Groundwater around Municipal waste disposal sites: a Review." *IOSR Journal of Engineering (IOSRJEN)*, 10(8), 2020, pp. 12-21.