Appendix A Groundwater quality studies from arid and semiarid areas worldwide

S/no	Region/Country	Study type	Methods used	Elements/parameters analysed	Results/Findings	Source
1	Las Cruces, New Mexico, USA.	Interaction between ephemerals channels and groundwater aquifers.	The water balance approach uses a dense instrument network and percolation through the independent method;	Rainfall (R), Evapotranspiration (ET), Closure-forced ET (ETF), Streamflow (Q), Soil moisture change (ZrDh/Dt), Percolation (P)	Infiltration occurs inside channel areas during the inundation event and less streamflow, leaving the watershed related to infiltration, resulting in outlet streamflow to rainfall ratio.	(Schreiner-McGraw and Vivoni, 2018).
2	Nirmal Province, South India.	Groundwater quality and human health risks of fluoride and nitrate contamination.	Hazard quotient (HQ) and total hazard index (THI)	pH, EC, TDS, F, NO_3^-, HCO_3^-, SO_4^{2-}, Cl^-, Na^+, Mg^{2+}, Ca^{2+}	About 26% and 20.59% of groundwater samples have elevated NO_3 and F levels, above the reference limits defined by the Bureau of Indian Standards (45 mg/L and 1.5 mg/L, respectively).	(Adimalla et al., 2018).
3	Semi-arid region of Basara, Telangana State, South India.	Geochemical characterization and evaluation of groundwater.	Systematic groundwater sampling and standard methods for the examination of groundwater.	pH, EC, TDS TH, Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^-, Cl^-, SO_4^{2-}, NO_3^{2-}, F, SAR, RSC, %Na^+, MH.	Groundwater is influenced by the water-rock processes through percolation and dissolution of rock-forming minerals, while the saturation index was less than zero, indicating under-saturation. The NO_3 and F concentrations were above the maximum permissible limit, indicative of anthropogenic input.	(Adimalla and Venkatayogi, 2018).

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4	Sfax coastal aquifer, Southeast Tunisia	Hydrochemical and statistical studies of groundwater. Salinization combined with the MODPATH numerical model.	Atomic absorption spectrometry, PCA, hierarchical ascending classification, kriging, MODFLOW, MODPATH.	pH, Cl, Br, NO_3^-, SO_4^{2-}, Na^+, Ca^{2+}, Mg^{2+}, K^+, HCO_3^-, CE, TDS.	The groundwater quality has worsened due to anthropogenic and natural processes with mineralisation and seawater intrusion in the aquifers.	(Boughariou *et al.*, 2018).
5	Semiaridbays of South Texas, USA.	Seasonal dynamics of dissolved Ra isotopes.	High purity Jewell gamma detector following the extraction and co-precipitation procedure (Isotope), ion chromatography, XRF.	Ra, CH_4, Cl^-, Br, soil core sediments.	Findings indicate that the studied bays display marked seasonal variability in Ra activity, leading to high absolute values. The mixing model result showed that supply from undersea groundwater discharge could balance the three bays' Ra budgets.	(Breier *et al.*, 2010).
6	Pike and Katarapko floodplains of the River Murray, Renmark, South Australia.	Floodplain recharge and groundwater mixing	Groundwater sampling from monitoring borehole and isotope technique	TDS, Cl^-, Br, Na^+, $\delta^{18}O$, δ^2H, ^{14}C, ^3H.	A correlation between ^3H activities and TDS and groundwater with relatively low ^{14}C activities but above detection ^3H activities implies that recently recharged waters have mixed with regional groundwater in the floodplain sediments.	(Cartwright et al., 2019).
7	Riyadh, Saudi	Hydrogeochemical	Integration of	Temp. pH, O_2, TDS, K^+,	Anthropogenic factors perhaps	(El Alfy et al., 2017).

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	Arabia.	processes are affecting groundwater pollution.	geochemical equilibrium and multivariate statistical techniques	Na^+, K^+, Ca^{2+}, Mg^{2+}, NO_3^-, NO_2^-, Cl^-, HCO_3^-, SO_4^{2-}, HPO_4, F, As, B, SiO_2, Hg.	contribute to further declines in the quality of groundwater.	
8	Eastern Africa coastal aquifer, Kwale County, south of Mombasa and adjacent to northern Tanzania.	Groundwater hydrodynamics.	Modelling, geophysical surveys, hydrochemical and isotopic sampling surveys	EC, Temp. pH, TOC, Alkalinity (as HCO_3(, HCO_3^-, DO, ORP, EH, NH_4^+, SO_4^{2-}, Cl^-, NO_3^-, PO_4^{3-}, Br, F, Ca^{2+}, Mg^{2+}, Na^+, K^+, Fe^{3+}, Si, Al, Li, Mn, $\delta^{18}O$, δ^2H.	There is a 69% drop in recharge than an average climatic year due to the drought (2016-17). There was a decline in recharge during the first rainy season (April–June) and no recharge during the second wet season (October–December). There was a concurrent increase in seawater intrusion even during the wet season.	(Ferrer *et al.*, 2019).
9	Malawi.	Systematic transboundary aquifer assessment.	Illustrative conceptual models of TBA interactions.	Groundwater aquifer modelling.	It conceptualised local scale complexity and encouraged countries to develop a strategy that thoroughly examines TBA systems along their national border. It allows for conjunctive policy creation and sustainable management of TBAs.	(Fraser *et al.*, 2018).
10	Tehran-Karaj aquifer, Iran.	Evaluating the primary sources of groundwater pollution	Multivariate Statistics (Principal	pH, TDS, EC, Turb., Temp., TH, Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^-, SO_4^{2-},	All the water quality parameters are above the Iranian drinking water	(Ghahremanzadeh *et al.*, 2018).

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			component factor analysis)	Cl^-, NO_3^-, NO_2^-, CO_3^-, TC, FC, Mn, Cd, Fe^{3+}, As, PAH, MTBE.	standard.	
11	Global review	NO_3 sources and operating processes.	The aspect of nitrate contamination.	NO_3^-	Nitrate isotopes ($\delta^{15}N$, $\delta^{18}O$, $\delta^{17}O$) can be applied to trace the source of N as mineral or organic fertilizer, sewage, or atmospheric deposition.	(Gutierrez et al., 2018a).
12	Mediterranean basin, North Africa.	Climate impact on surface and groundwater.	A global synthesis of findings and recommendations.	TDS.	Water monitoring networks show apparent hydrogeologic discrepancies and an increase in groundwater salinity.	(Hamed et al., 2018).
13	Qazvin plain, Iran.	Optimization of the interpolation method for nitrate pollution in groundwater	NO_3^- sampling and analysis, geostatistics.	NO_3^-	Results indicate that the National neighbour with the lowest RME was preferable to the other spatial interpolation technique to predict NO_3 concentration in the aquifer.	(Kazemi *et al.*, 2017).
14	Nueces River, Texas, USA.	Impact of hydrological alterations on river-groundwater exchange and water quality.	A novel combination of electrical resistivity tomography (ERT) and elemental and isotope geochemistry.	$\delta^{18}O$, δD, $\delta^{13}C$, DIC, ^{222}Rn, Cl^-, SO_4^{2-}, Br, Ca^{2+}, Na^+, Mg^{2+}, Mn.	The contribution of surface flows (i.e., surface water releases or groundwater discharge) related to the river crumbling governs stream-water chemistry variations and perhaps influences the reading of seasonal trends.	(Murgulet *et al.*, 2016).
15	Central Arava Valley, Israel.	Contamination of groundwater under	A combination of physical, chemical,	Na^+, K^+, Cu^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, NO_3^-, Br,	Two major pollution processes were identified, both related to	(Oren *et al.*, 2004).

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		cultivated fields.	and isotopic analyses.	Sr, TDS, TOC, $^{15}N_{NO3}$, δ $^{18}OH_2O$, Trinium (TU)	human activity: (a) salinization due to the circulation of dissolved salts in the irrigation water itself, mainly Cl^-, SO_4^-, Na^+, and Ca^{2+}, and (2) direct application of NO_3^- and K^+ primarily from fertilizers.	
16	Ou-Areg coastal plain of Morocco	Tackling the salinity-pollution nexus in coastal aquifers.	NO_3^- and B isotopes.	$^{15}N_{NO3}$, δ $^{18}O_{NO3}$, B, Cl^-, SO_4^{2-}, Na^+, K^+, Ca^{2+}, δ" B, Br.	The high concentrations of B and Cl^-, related to the complex water-mineral rock interaction, limit the use of the coupled δ^{11}Band δ^{15}N isotopes to the trace sources of groundwater contamination.	(Re and Sacchi, 2017).
17	Ngabu, Southern Malawi	Responding to salinity in a rural African alluvial valley aquifer system.	A processes-based conceptual model relevant to the drinking-water supply	pH, EC, TDS, CO_3^{2-}, HCO_3^-, NO_3^-, HCO_3^-, Cl^-, SO_4^-, Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{3+}, Mn.	While salinity is theorized to arise from evaporite dissolution, shallow groundwater evaporation, and faulted area upsurge, insufficient data locally renders salinity sources' provenance to specific boreholes problematic.	(Rivett *et al.*, 2019).
18	Chikwawa District, Malawi.	A conceptual model-based framework for pragmatic groundwater-quality monitoring network design.	A stepwise 'framework' network-design methodology.	HCO_3^-, Cl^-, Na^+ and Ca^{2+}, Mg^{2+}, TDS.	The framework, as established, permits an incremental build of a prioritized network of points, with a close approximation of	(Rivett *et al.*, 2018).

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					their potential to address the specific monitoring points set.	
19	Goshen Valley, UT, USA.	Investigating Anthropogenic and Geogenic Sources of Groundwater Contamination	Nonmetric multidimensional scaling (NMS).	As, B, Ba, Fe^{3+}, K, Li, Mg^{2+}, Mn, Mo, Pb, Si, Sr, Zn^{2+}.	Most NO_3-polluted bores contained ancient groundwater (based on ^{14}C and ^{3}H), signifying that NO_3 pollution is derived from re-infiltration groundwater.	(Selck et al., 2018).
20	Deccan Volcanic Province, Maharashtra, India	Assessment of aquifer zones and their protection via second-order geoelectric indices.	Vertical electrical sounding and Schlumberger electrode configuration and the data analysis.	Modelling.	Results indicate a strong positive correlation between the percentage of clay fraction and longitudinal conductance.	(Gupta *et al.*, 2019).
21	Zhangye Basin, China.	Modelling ground-surface water interaction.	Modelling	Precipitation, GW lateral inflow, Horizontal and vertical hydraulic conductivity, Hydraulic conductivity of streambed, Specific yield, soil's maximum available capillary water-holding capacity, Maximum depth where evapotranspiration can occur, Maximum possible area contributing to surface runoff.	The model formed a holistic view of the hydrological cycle impact by agricultural water use and generated insights into the spatial and temporal patterns of the SW-GW interaction after a successful calibration. In addition, diverse water resources management setups were also assessed.	(Tian *et al.*, 2015).
22	Brisbane, Australia	Greywater irrigation is a source of organic	Water sampling	Acesulfame, Caffeine,	Greywater comprises many micropollutants hitherto	(Turner et al., 2019).

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		micro-contaminates to shallow groundwater and surface.	from piezometers	DEET, Paracetamol, Salicylic acid, Triclosan.	unknown about their possible ecological fate when used in irrigated fields.	
23	Hamedan, Iran.	Landfill leachate and its impact on the groundwater quality.	Time-series sampling and PCA	COD, BOD, TOC, EC, NO_3^-, Cl^-, TDS, pH.	The time-series analysis shows that the decomposition of leachates correlated with rainfall events.	(Vahabian *et al.*, 2019b).
24	Tigris-Euphrates-Western Iran region	Groundwater depletion in the Middle East.	Global GRACE data set.	GIS/Remote sensing.	The region lost 17.362.1 mm yr^{-1} between 2003 and 2009, equivalent water height of groundwater during the study period, or 91.3610.9 cubic metres in volume.	(Voss *et al.*, 2013).
25	Tengger Desert, northwestern China.	Spatiotemporal variation of groundwater quality	Field sampling and laboratory analysis.	COD_{Cr}, Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^-, Cl^-, SO_4^{2-}, TDS, NH_4-N, NO_3-N, NO_2–N, F, pH, COD_{Mn} TH, Fe^{3+}, Mn, colour.	F, NO_2 and NH_4, and the COD are the significant contaminants identified in some groundwater monitoring wells	(Wu *et al.*, 2017).
26	Semiaridkarst region, Jordan.	Contamination risk and drinking water protection.	Time series geological and hydrogeological (2012-13), Total coliform and E. coli data (2003–2012).	Correlation of rainfall and microbial occurrence.	Findings indicate an extreme pollution risk after livestock farming, arable agriculture, and human habitation.	(Xanke *et al.*, 2017).
27	Tebessa plain,	Impacts of natural conditions and	Geostatistical interpolation and	EC, Ca^{2+}, Mg^{2+}, Na^+, K^+,	The PCA and ionic ratios indicate that groundwater	(Zereg *et al.*, 2018).

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	Algeria.	anthropogenic activities on groundwater quality	multivariate statistical approach.	Cl^-, SO_4^{2-} HCO_3^-, NO_3^-.	quality's temporal variability was consequent to rock weathering. The NO_3 in groundwater was derived from excessive chemical N fertilizers, organic composts, and wastewater seepages.	
28	Jinghui canal, northwest China	Human health risk assessment of groundwater nitrogen pollution.	Field sampling and laboratory analysis of physicochemical indices, Comprehensive water quality index.	pH, TDS, TH, Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, CO_3^-, Cl and SO_4^{2-}, NO_3-N, NO_2-N, NH_4-N.	Evaporation and rock weathering are chief natural processes controlling groundwater chemistry.	(Zhang. *et al.*, 2018).
29	Highland Areas of South-eastern Sokoto Basin, Nigeria.	Variability in aquifer depths dominates the composition of groundwater.	Field sampling and laboratory analysis of physicochemical indices, SAR, Ki, MH, Na (%).	pH, EC, TDS, K^+, Na^+, Ca^{2+}, Cu^{2+}, Fe^{3+}, Zn^{2+}, and Mg^{2+}, Cl^-, HCO_3^-, CO_3^-, PO_4^{3-}, NO_3^-, and SO_4^-.	While shallow groundwater can be used for irrigation with little or no risk of MH hazard to crops, the underlying reason for high Mg and deep shallow need to be understood.	(Wali *et al.*, 2018).
30	Northern Kebbi State, Nigeria.	Shallow Groundwater in Cretaceous and Tertiary Aquifers.	Field sampling and laboratory analysis of physicochemical indices, SAR, Ki, MH, Na (%).	pH, TDS, EC, water table, Temp., TH, Na^+, K^+, Ca^{2+}, Mg^{2+}, Zn^{2+}, Fe^{3+}, Cu^{2+}, Cl^-, SO_4^-, HCO_3^-, NO_3^-, PO_4^{3-}, CO_3^{2-}.	The area contains water of excellent quality for drinking and irrigation use.	(Wali, *et al.*, 2018).