

SUPPLEMENTARY INFORMATION

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SUPPLEMENTARY APPENDIX A

Data extraction table

The table below summarizes the characteristics of each of the 15 primary regional studies included in the review following the PRISMA process (Section "Materials and methods"; Figure 1). For each study, the table reports the source, year of publication, geographical area, methodological approach, main indicator(s) reported, and the level of evidence validation assigned according to the five-level framework described in Section "Evidence validation framework". This data extraction table is provided to facilitate independent replication of the review, as specified in Section "Availability of the data extraction table and protocol".

Table A1. Characteristics of the 15 included regional studies

Study	Year	Geographic area	Method	Indicator(s) reported	Level of evidence
Hilali et al.	2020	Oued Day, Béni Mellal	GIS techniques and pollution indices	Metallic pollution of irrigated agricultural soils	3
Hilali et al.	2021	Oued Day, Béni Mellal	Multi-criteria analysis of GIS and AHP	Soil quality of agricultural soils irrigated by wastewater	3
Hilali et al.	2022	Oued Day, city of Beni Mellal	Soil profile/column tracking	Distribution of heavy metals in the irrigated soil profile	3
El Hamzaoui et al.	2020	Beni-Moussa, Tadla plain	Spatial distribution and assessment of contamination	Heavy metals in agricultural soils	3
Ennaji et al.	2020	Northeast of the Tadla plain	Ecological risk assessment	Metal contamination in agricultural soil	3
Oumenskou et al.	2018	Beni Amir, Tadla plain	GIS approach and pollution indices	Metal contamination of agricultural soils	3
Aallam et al.	2021	Beni Mellal (sugar beet field)	Soil contamination assessment	Toxic trace elements in the soil	3
Barakat	2020	Beni Moussa perimeter, Tadla plain	Groundwater sampling and health risk indices	Nitrate concentration and health effects	3
Barakat et al.	2019	Beni Amir irrigated perimeter, Tadla plain	Health risk assessment	Nitrates in groundwater	3
El Baghdadi et al.	2019	City of Beni Mellal	Statistical analysis of monitoring data	Urban groundwater quality	3
Barakat et al.	2020	City of Beni Mellal (peri-urban area)	Environmental and health risk assessment	Metal contamination, peri-urban soils	3
Aadraoui et al.	2018	Khouribga	Sludge characterization	Properties of sewage sludge (compatibility with construction materials)	3
Ait Ouhamchich et al.	2018	Boujaâd, Khouribga province	Evaluation of WWTP performance	COD/BOD5/TSS reduction, climate sensitivity	3

Hafiane et al.	2024	Tadla Plain (well water)	Microbiological sampling and resistance profiling	Antibiotic resistance of <i>Salmonella</i> spp.	3 (single non-replicated study)
Faouzi et al.	2020	Béni Mellal-Khénifra Region (6 WWTPs)	Technical performance monitoring + survey of farmers/residents	Performance of wastewater treatment plants; social perception; climate adaptation	3

SUPPLEMENTARY APPENDIX B

Formalized review protocol

This appendix consolidates, in a formalized protocol, the methodological elements of the review described in Section "Materials and methods". It is provided to enhance methodological transparency and facilitate independent replication of the review, as described in Section "Availability of the data extraction table and protocol".

Research questions

- Central research question: To what extent does the available scientific and institutional literature permit an integrated assessment of the environmental and health trajectory associated with wastewater reuse and sludge recovery in the Béni Mellal-Khénifra region?
- Sub-question 1: What is the extent and nature of regional research gaps relative to the national and international literature?
- Sub-question 2: What methodological limitations affect the reliability of the available academic and institutional evidence?
- Sub-question 3: What research priorities are best suited to address these gaps, taking into account regional feasibility constraints?

Search strategy and databases

The following platforms and databases were searched: SpringerLink, Nature/Scientific Reports, MDPI, ScienceDirect, Wiley Online Library, DOAJ/E3S Web of Conferences, ResearchGate, Academia.edu, European Scientific Journal, and DergiPark.

The following search queries were used:

- Query 1: "wastewater reuse sludge valorisation Béni Mellal Morocco"
- Query 2: "Béni Mellal Khénifra sewage sludge valorisation agricultural indexed journal"
- Query 3: "antibiotic resistance genes wastewater treatment plant Morocco groundwater Tadla"
- Query 4: "systematic review PRISMA wastewater reuse Morocco social acceptability farmers"
- Query 5: "sludge Khouribga OR Fkih Ben Salah OR Boujaad wastewater treatment plant characterization"
- Query 6: "El Hamzaoui El Baghdadi Beni Moussa Tadla heavy metals soil 2020"
- Query 7: Author verification request concerning the study on antimicrobial resistance in Tadla groundwater.
- Query 8: Author verification request concerning the study on soil contamination in sugar beet cultivation in Béni Mellal.

Eligibility criteria

– Inclusion criteria: Primary studies reporting data collected in the Béni Mellal-Khénifra region, including the Tadla plain and/or the Oum Er-Rbia basin, and addressing wastewater reuse, wastewater treatment plant (WWTP) performance, sludge characterization or valorisation, or soil or groundwater contamination attributable to wastewater or sludge.

– Exclusion criteria: Studies conducted in other regions of Morocco; studies addressing environmental topics unrelated to wastewater reuse or sludge despite keyword matches; and grey or institutional literature lacking sufficient methodological detail. The latter was retained separately as contextual or regulatory evidence where relevant.

Evidence validation framework

Evidence was classified according to the following five-level framework:

- Level 1: Meta-analyses and systematic reviews.
- Level 2: Experimental field studies with replication and control groups.
- Level 3: Single-site field studies with a detailed methodological protocol (the modal category within the regional corpus).
- Level 4: Institutional reports that were not peer-reviewed.
- Level 5: Press releases and official statements (contextual evidence only).

A mandatory triangulation rule was applied before a claim was considered sufficiently supported.