

REUSE OF TREATED WATER AND SLUDGE FROM WASTEWATER TREATMENT PLANTS IN THE BÉNI MELLAL-KHÉNIFRA REGION, MOROCCO: A CRITICAL LITERATURE REVIEW

Mohamed El Hannani^{1*}, Salah Touil^{1,2}

¹Laboratory of Processes, Energy, Materials and the Environment (LPEME), National School of Applied Sciences, University Sultan Moulay Slimane, Beni-Mellal, Morocco

²Laboratory of Industrial, Energy and Environmental Engineering (LGIEE), University Sultan Moulay Slimane, Beni-Mellal, Morocco

*Corresponding email: mohamed.elhannani@usms.ma

Received: 02.08.2026; **Accepted:** 11.08.2026; **Available online:** 17.08.2026; **Published:** 30.09.2026

Cite this article: El Hannani, M., & Touil, S. (2026). Reuse of treated water and sludge from wastewater treatment plants in the Béni Mellal-Khénifra region, Morocco: a critical literature review. *Trends in Ecological and Indoor Environmental Engineering*, 4(3), 28–34.

Background: Morocco is increasingly relying on treated wastewater reuse and sewage sludge valorisation to address structural water stress, climate change, and growing demographic and industrial pressures. In the Béni Mellal-Khénifra region, recent large-scale tertiary wastewater treatment investments by OCP Green Water coexist with a substantial body of research documenting metal contamination of irrigated soils and groundwater. However, these two hydrological realities have not yet been critically integrated. **Objectives:** This study maps the regional and national research landscape, verifies three hypothesized research gaps, evaluates the credibility of available evidence, and proposes a priority research program for sustainable wastewater reuse and sludge valorisation. **Methods:** A PRISMA-guided critical literature review was conducted. An exploratory scoping search generated three hypotheses, followed by a formal eight-query identification and selection process that retrieved 63 records and retained 15 primary regional studies. A five-level evidence-validation framework was applied, with mandatory triangulation of quantitative claims derived from institutional or non-peer-reviewed sources. The review also explicitly assessed methodological limitations, source concentration, and the reproducibility of the evidence base. Key limitations included the reliance on open academic sources without systematic access to a single proprietary bibliographic database such as Scopus or Web of Science, the concentration of the regional academic corpus within two overlapping research teams at Sultan Moulay Slimane University, and the reliance of several recent infrastructure estimates on a single institutional source chain without independent audit. The underlying evidence was further limited by small sampling sizes, scarce control groups and longitudinal datasets, and heterogeneous reference thresholds across studies. **Results:** Three research gaps were largely confirmed. Integrated health–environmental assessment remains incomplete: metal contamination is relatively well documented locally, but emerging contaminants and the integration of antimicrobial resistance with chemical contamination are virtually unexplored. Governance and social acceptability are only partially addressed, with one study assessing farmers’ and residents’ perceptions but none examining institutional governance. Longitudinal contaminant monitoring is absent, and climate coupling remains limited. Most importantly, no published study links the documented historical contamination of irrigated soils with the effects of the new OCP Green Water tertiary treatment infrastructure. A regulatory gap concerning quality standards for sludge intended for agricultural spreading was also identified. The evidence base is further constrained by small samples, limited controls and time series, heterogeneous reference thresholds, and reliance on unaudited institutional infrastructure data. **Conclusion:** This first integrated regional synthesis provides an evidence-validation framework and a seven-pronged research agenda. It highlights priorities for independent monitoring, integrated contaminant and antimicrobial-resistance assessment, governance research, and sludge regulation before further expansion of wastewater reuse.

Keywords: wastewater reuse; sewage sludge valorisation; Béni Mellal-Khénifra; Oum Er-Rbia basin; metal contamination of soils; antimicrobial resistance; water governance; Morocco.

INTRODUCTION

Morocco faces structural water stress, exacerbated by climate change and increasing demographic and industrial pressure. This has led the government to make the use of unconventional water resources, including treated wastewater, seawater desalination, and water transfer, a national strategic priority, formalized since 2016 by the Water Law (Law 36-15) and framed, with regard to irrigation water quality, by the joint decree of 2002 (Kingdom of Morocco, 2002; Kingdom of Morocco, 2016). National indicators show a clear acceleration: the network of wastewater treatment plants (WWTPs) has reached approximately 150–187 units, with a wastewater treatment rate of approximately 57.5% in 2024, against a target of 80% for 2050, alongside an increasing emphasis on water reuse rather than wastewater treatment solely to meet discharge standards. This shift reflects the broader transition from pollution control towards resource recovery and water reuse. The national stockpile of associated sludge is estimated at approximately 110,000 tonnes of dry matter (t DM) in 2020, with a projection of approximately 420,000 t DM by 2030, reflecting a growing policy focus on valorising this resource, previously regarded primarily as a burden and constraint.

The Béni Mellal-Khénifra region, centred on the Oum Er-Rbia River Basin and encompassing the phosphate plateau and the

Tadla agro-industrial plain, presents a unique profile: a major phosphate mining industry and a dense agri-food sector (sugar mills, olive oil mills, and dairies), whose treated effluents may present a different contaminant signature from that documented elsewhere in Morocco, alongside a well-established local academic research community that has documented for more than a decade the metallic contamination of agricultural soils irrigated by the waters of the Oued Day and the irrigation perimeters of Beni Moussa and Beni Amir (Hilali et al., 2020, 2021, 2022; Barakat et al., 2020; El Hamzaoui et al., 2020; Ennaji et al., 2020; Oumenskou et al., 2018; Aallam et al., 2021). Since 2024, the region has experienced a marked acceleration in investment in tertiary wastewater treatment, driven mainly by the OCP Group through its subsidiary OCP Green Water, with the aim of securing the industrial water supply for its phosphate processing operations in Khouribga and progressively reducing reliance on conventional water resources through desalination and treated wastewater reuse. This juxtaposition of recent industrial water infrastructure and longstanding environmental risk signals has not, to our knowledge, been examined through an integrated critical synthesis.

This raises a central research question: to what extent does the available scientific and institutional literature support an integrated assessment of the environmental and health

implications of wastewater reuse and sludge valorisation in the Béni Mellal-Khénifra region? This question is addressed through three sub-questions: (1) what is the extent and nature of regional research gaps compared with the national and international body of work; (2) what methodological limitations affect the reliability of available data, whether academic or institutional; and (3) what research priorities would be best suited to address these gaps, considering regional feasibility constraints.

Objective of the research

This article aims to (i) map the available research landscape on sludge reuse and valorisation at national and regional scales; (ii) empirically assess three hypothesized research gaps identified through an exploratory scoping review; (iii) assess the credibility and methodological quality of the sources using an explicit validation framework; and (iv) propose a prioritized research agenda.

MATERIALS AND METHODS

Review design and search strategy

This review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach for the identification, selection, and eligibility assessment, adapted for a regionally focused critical literature review rather than a clinical meta-analysis. An initial exploratory scoping search (not included in the formal PRISMA count) targeted general queries on national sludge reuse and valorisation policy, identifying three layers of the research landscape (national policy/engineering; national sludge agronomy; region-specific work) and generating three hypothesized research gaps that guided the subsequent formal search.

The formal identification step used eight search queries conducted across academic publisher platforms and aggregators (Springer Link, Nature/Scientific Reports, MDPI, ScienceDirect, Wiley Online Library, DOAJ/E3S Web of Conferences, ResearchGate, Academia.edu, European Scientific Journal, and DergiPark), namely: (1) "wastewater reuse sludge valorisation Béni Mellal Morocco"; (2) "Béni Mellal Khénifra sewage sludge valorisation agricultural indexed journal"; (3) "antibiotic resistance genes wastewater treatment plant Morocco groundwater Tadla"; (4) "systematic review PRISMA wastewater reuse Morocco social acceptability farmers"; (5) "sludge Khouribga OR Fkih Ben Salah OR Boujaad wastewater treatment plant characterization"; (6) "El Hamzaoui El Baghdadi Beni Moussa Tadla heavy metals soil 2020"; (7) an author verification request concerning the study on the antimicrobial resistance of groundwater in Tadla; (8) an author verification request concerning the study on soil contamination in sugar beet fields in Béni Mellal. This process is fully documented in the PRISMA flow diagram (Figure 1).

Eligibility criteria and selection

Records were included if they (i) reported primary data collected specifically in the Béni Mellal-Khénifra region or the Tadla Plain/Oum Er-Rbia Basin, and (ii) addressed wastewater reuse, wastewater treatment plant (WWTP) performance, sewage sludge characterization or valorization, or soil/groundwater contamination associated with wastewater or sludge. Records were excluded if they concerned another region or country, if they dealt with an unrelated environmental topic despite a regional keyword match (e.g., unrelated agronomy, unrelated microbiology from another country), or if they were grey/institutional literature lacking sufficient methodological detail for inclusion as primary studies. National laws, ministerial statements, and press releases were retained

separately as contextual/regulatory references but were not counted among the included primary studies.

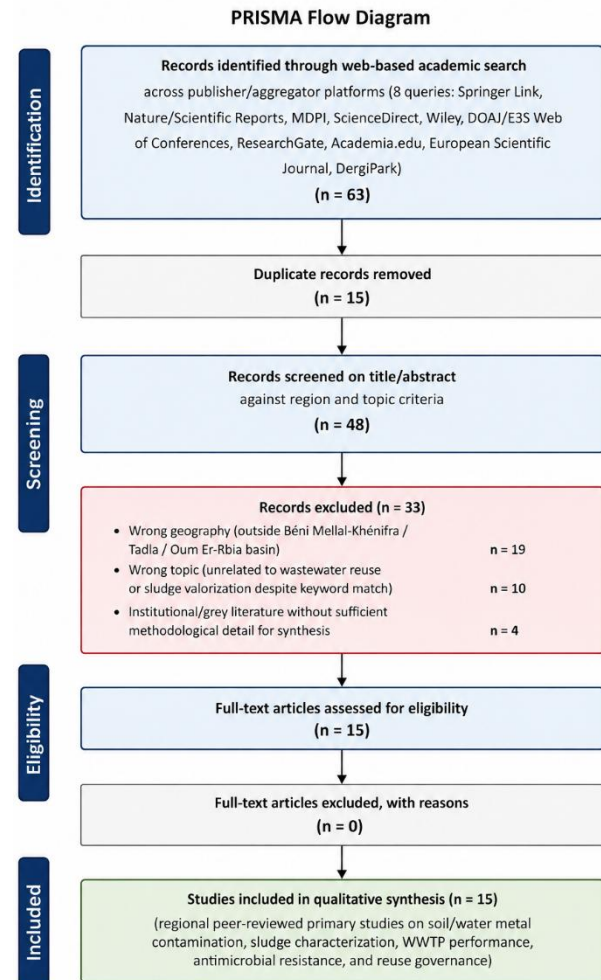


Figure 1. PRISMA flowchart documenting the identification, selection, eligibility and inclusion of the 15 primary regional studies synthesized in this review

Evidence validation framework

In addition to the PRISMA selection, a five-level validation framework was applied to each retained claim: (1) meta-analyses and systematic reviews; (2) replicated experimental field studies with control groups; (3) single-site field studies with a detailed protocol (the predominant category in the regional corpus); (4) non-peer-reviewed institutional reports; and (5) press releases and official statements, used only as contextual evidence of recent infrastructure. Each quantitatively significant claim derived from a level 4 or 5 source was subjected to a triangulation rule, requiring confirmation from at least two independent sources before being considered reliable.

Methodological limitations of the review

This synthesis relies on online academic searches rather than direct searches of proprietary bibliographic databases such as Scopus or Web of Science. Although the retrieved records come from indexed publisher platforms and aggregators, the exact overlap with a formal Scopus/Web of Science search export could not be independently verified. Furthermore, the included regional academic corpus is concentrated within two overlapping research teams at Sultan Moulay Slimane University, introducing a potential institutional or school-of-thought bias that cannot be fully excluded in the absence of independent replication.

Availability of the data extraction table and protocol

To enhance the reproducibility of this review, a structured data extraction grid, compiling the source, year of publication, geographical area, methods, reported indicators, and evidence-validation level for each of the 15 included studies, as well as a fully formalized review protocol (research questions, search strategy, list of databases and queries, eligibility criteria, and evidence-validation framework), are provided as supplementary information (Appendix A and Appendix B, respectively) to allow independent replication of the review process.

RESULTS

Overview of sludge reuse and recovery channels

Figure 2 summarizes the reuse and recovery channels for sludge identified for the region: treated wastewater is divided between industrial use (phosphate washing on OCP operations in Khouribga) and agricultural use targeted at the national level but poorly documented locally, while the sludge ends up mostly in landfill rather than in agronomic recovery.

Simplified scheme of wastewater reuse and sludge valorization pathways in the Béni Mellal-Khénifra region

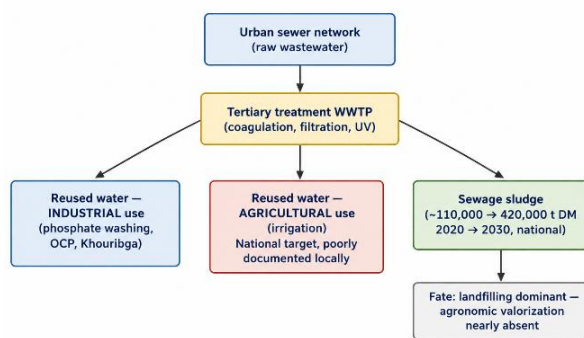


Figure 2. Simplified diagram of wastewater reuse and sludge recovery channels in the Béni Mellal-Khénifra region (authors' diagram)

Regulatory framework and its regional application

Law 36-15 integrates wastewater into the public water domain (Arts. 64–71) and mandates sludge treatment according to its characteristics and intended use (Kingdom of Morocco, 2016). The quality of irrigation water, including treated wastewater, is governed by the 2002 joint decree (Kingdom of Morocco, 2002). The 2010 National Sludge Management Strategy identifies several recovery pathways, but its implementation is still considered insufficient by the authorities themselves (Ministry of Energy Transition and Sustainable Development, 2025). No Moroccan standard specifically establishing quality thresholds for sludge intended for agricultural spreading could be identified in the sources reviewed (Soudi & El Khoumsi, 2024); this regulatory gap is, in itself, a finding of this review.

This observation is corroborated and substantially expanded upon by the 2024 FAO national report on the management and agricultural use of sewage sludge in Morocco (Soudi & El Khoumsi, 2024), which to date constitutes the most recent, comprehensive, and systematically documented institutional synthesis available on the subject. This report was the subject of a broad national feedback workshop in 2025, bringing together the main Moroccan entities responsible for the sector (Ministry of the Interior, Ministry of Energy Transition and Sustainable Development, ONEE, River Basin Agencies), which gives it particular institutional legitimacy compared to the other contextual sources used in this review. The report estimates national sludge production at approximately 170,000 t DM/year in 2024 (compared to a previous estimate of approximately 110,000 t DM for 2020 used in Table 1), estimates that approximately 60% of the sludge produced is currently sent to controlled landfills due to the lack of a structured recovery sector, and explicitly confirms the absence of a Moroccan standard specific to trace metals in sludge intended for agricultural spreading, recommending the development of a National Master Plan for sludge management and a priority action plan for 2030.

Table 1. National and regional order of magnitude data and level of triangulation

Indicator	Reported value	Level of triangulation
Wastewater treatment rate	57.5% (2024); target: 80% (2050)	Triangulated
Volume of wastewater reused	Approximately 71 Mm ³ yr ⁻¹ (2020); target: 325–340 Mm ³ yr ⁻¹	Triangulated (FAO; Ministry)
Sludge stockpile	Approximately 110,000 t DM (2020), projected to reach approximately 420,000 t DM by 2030	Triangulated (FAO; literature)
Beni Mellal Wastewater Treatment Plant (OCP)	MAD 593 million; approximately 9 Mm ³ yr ⁻¹ announced	Untriangulated (single source)
Kasbat Tadla WWTP (OCP)	MAD 403 million; 2.2 Mm ³ yr ⁻¹	Untriangulated (single source)
Fkih Ben Salah WWTP (OCP)	MAD 884 million; 5.5 Mm ³ yr ⁻¹	Untriangulated (single source)
Antimicrobial resistance of groundwater (Tadla)	58.1% multidrug-resistant strains (n = 200 samples)	Unique, unreplicated study

These elements directly reinforce the finding of a regulatory gap established by this review and suggest that the National Shared Sanitation Program (PNAM), which has structured the national sanitation policy since 2019, should explicitly include a sludge component with standards and an implementation schedule.

National and regional order-of-magnitude data

Table 1 summarizes the main orders of magnitude identified,

together with an indication of the level of triangulation obtained for each indicator and the degree of confidence associated with the available evidence. Figures 3 and 4 schematically locate the main wastewater treatment plants (WWTPs) mentioned within the Oum Er-Rbia basin and show the geographic distribution of wastewater treatment plants (WWTPs) across the Béni Mellal-Khénifra region by province, providing complementary spatial context for the regional analysis.

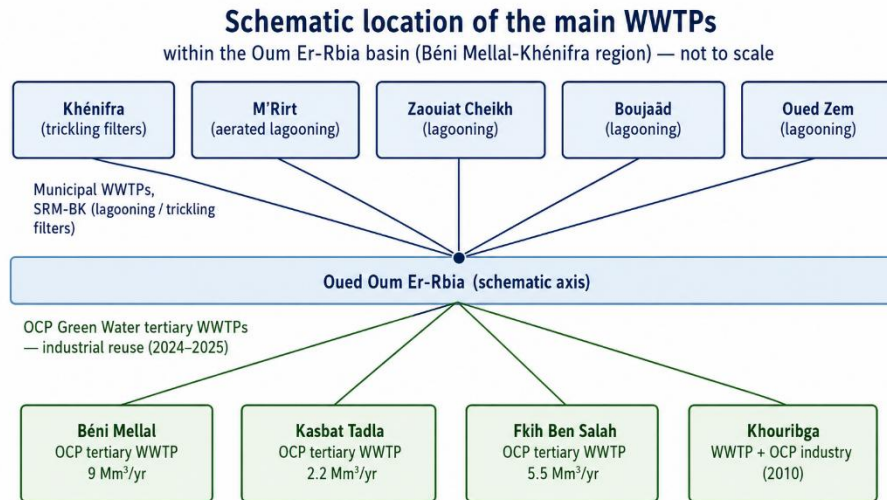


Figure 3. Schematic location of the main WWTPs mentioned in this review within the Oum Er-Rbia basin (relative positions, without scale)

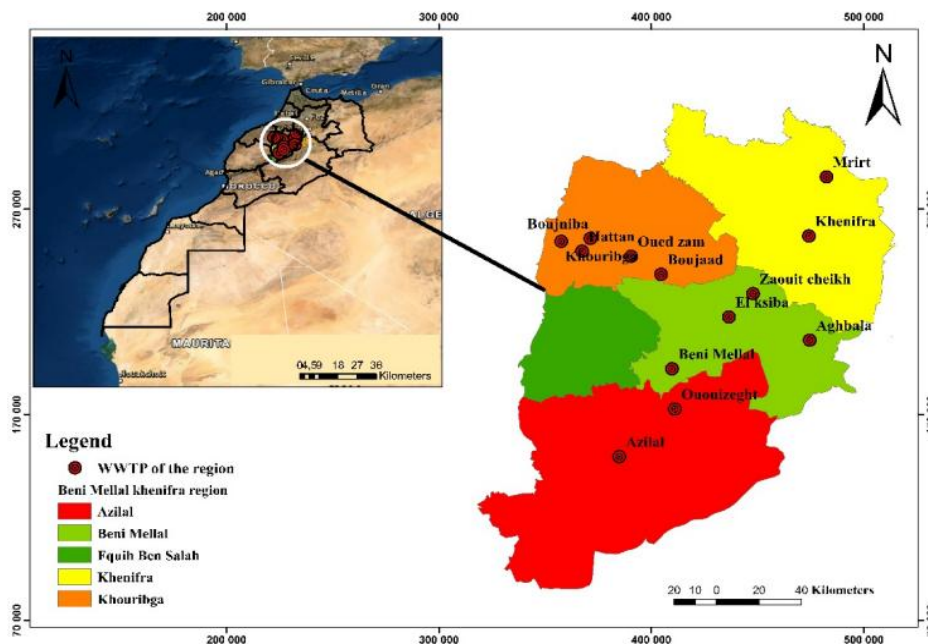


Figure 4. Geographic location of wastewater treatment plants (WWTPs) in the Béni Mellal-Khénifra region, by province (Azilal, Béni Mellal, Fkih Ben Salah, Khénifra, Khouribga). Source: adapted from Talbi et al. (2025)

The announced capacities and investment costs of the three OCP Green Water tertiary wastewater treatment plants are visualized in Figure 5, highlighting the scale of recent regional infrastructure investments and their potential significance for water reuse. Figure 6 complements these infrastructure data by showing the estimated national sewage sludge production in 2020 and its projected increase by 2030. Taken together, these data highlight a central contrast: nationally aggregated data benefit from reasonable triangulation between independent institutional sources, whereas the most recent data on regional infrastructure rely primarily on a single institutional source chain, limiting independent verification and requiring greater caution in interpreting these announced regional figures.

Synthesis of the 15 included regional studies

The 15 studies selected at the end of the PRISMA process (Figure 1, Section 2) cover five thematic groups, summarized in Table 2.

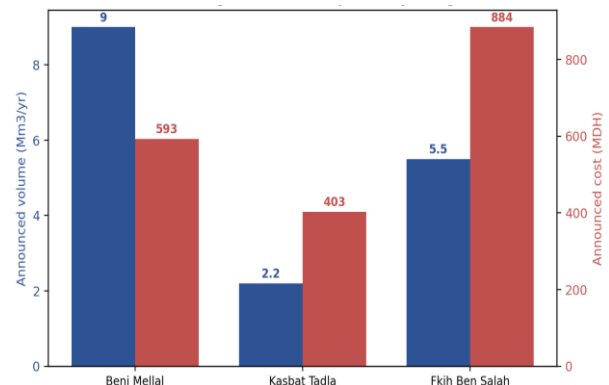


Figure 5. OCP Green Water tertiary wastewater treatment plants in the Béni Mellal-Khénifra region (2024–2025): announced design capacities (Mm³/year) and investment costs (MDH). Data represent announced design values and have not been independently audited

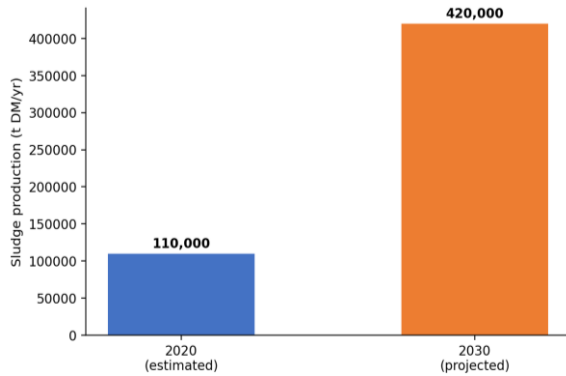


Figure 6. National sewage sludge production: estimated for 2020 and projected for 2030 (tonnes of dry matter/year)

The recurrent metal contamination patterns identified across the included studies are synthesized in Figure 7, illustrating the documented sequence from wastewater irrigation to metal accumulation in upper soil horizons and vertical Cd migration, with potential delayed groundwater contamination remaining unconfirmed by direct monitoring. This synthesis clarifies one of the three hypothetical gaps identified during the exploratory scoping phase. Faouzi et al. (2020) already combines monitoring the performance of wastewater treatment plants with a survey of farmers and neighboring residents in the Béni Mellal-Khénifra region itself, partially closing the governance/acceptability gap; however, this single study deals with the general perception of treated water quality rather than a governance analysis dedicated to the specific institutional mechanisms for reuse (Oum Er-Rbia River Basin Agency, OCP Green Water, SRM-Béni Mellal-Khénifra, municipalities, water user associations), so the gap is narrowed rather than closed.

Table 2. Thematic groups of the 15 regional studies included

Band	Studies included	Main result
Metal contamination of the soil (Oued Day, Beni Moussa, Beni Amir)	Hilali et al., 2020; Hilali et al., 2021; Hilali et al., 2022; El Hamzaoui et al., 2020; Ennaji et al., 2020; Oumenskou et al., 2018; Aallam et al., 2021	Recurrent accumulation of As, Cd, Cr, Cu, Ni, Pb, and Zn in irrigated soils; Cd migrates vertically up to 90 cm; sugar beet soils independently confirm the same metallic signature
Groundwater quality and health risks	Barakat, 2020; Barakat et al., 2019; El Baghdadi et al., 2019; Barakat et al., 2020 (peri-urban soils)	High health risk indices related to nitrates and metals in the groundwater and peri-urban soils of Beni Moussa and Beni Amir
Characterization/performance of sludge and wastewater treatment plants	Aadraoui et al., 2018; Ait Ouhamchich et al., 2018	The sludge from Khouribga is geotechnically compatible with construction materials (not for agricultural use); the Boujaâd lagoon achieves a 66–86% reduction in COD/BOD5/TSS, but performance is sensitive to climate
Antimicrobial resistance	Hafiane et al., 2024	58.1% of Salmonella isolates from wells in the Tadla plain are multidrug-resistant; no wastewater-to-groundwater pathway has been directly confirmed
Governance of reuse, climate adaptation and farmers' perceptions	Faouzi et al., 2020	Six regional WWTPs were evaluated with a survey of neighbouring farmers; the only regional study combining technical performance and a social perception component

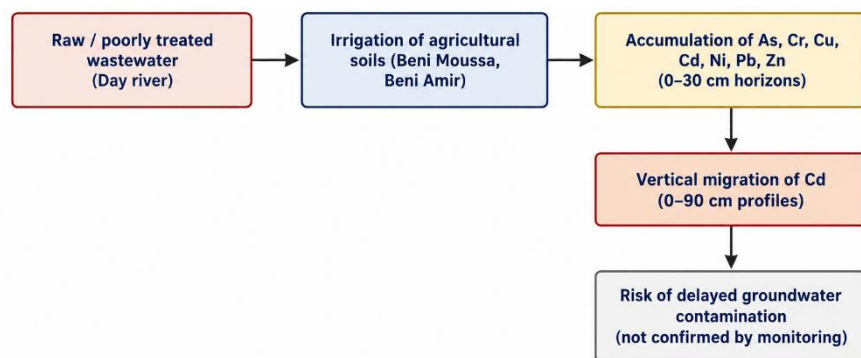


Figure 7. Conceptual diagram of the metal contamination mechanism documented in irrigated soils of the Tadla plain, synthesized from the 15 included studies (Hilali et al., 2020, 2021, 2022; El Hamzaoui et al., 2020; Ennaji et al., 2020; Oumenskou et al., 2018; Aallam et al., 2021)

The result on antimicrobial resistance by Hafiane et al. (2024) remains a single, unreplicated study, and none of the included studies combine it with metal contamination or emerging contaminants in an integrated protocol. No included study specifically addresses the agronomic valorisation of sludge for the region; the only regional sludge characterization study

(Aadraoui et al., 2018) assessed compatibility with construction materials rather than agricultural spreading. Climate sensitivity highlights that the same process can show different performances depending on the indicator chosen (El Hannani et al., 2026), hence the interest in standardized indicators for future monitoring of regional wastewater treatment plants.

Verification of the three hypothetical research gaps

The three hypothetical research gaps identified during the exploratory scoping review were subsequently assessed against

the evidence retrieved through the PRISMA-based review. Table 3 summarizes the degree to which each gap was confirmed, qualified, or only partially supported by the available literature.

Table 3. Status of hypothetical research gaps following the PRISMA-based review

Hypothetical gap	Status	Evidence to support
(a) Integrated health-environmental assessment	Confirmed for the fully integrated version; nuanced for the metals component alone, which is relatively well documented (9 of the 15 studies included)	9 converging studies on metals/nitrates; 1 study on antimicrobial resistance; 0 studies on emerging contaminants or those combining metals and antimicrobial resistance
(b) Governance and social acceptability	Focused, but not exhaustive: 1 included study (Faouzi et al., 2020) focuses on the perceptions of farmers/residents, but no study dedicated to institutional governance exists.	One of the 15 included studies deals with perception; 0 studies specifically address governance
(c) Longitudinal monitoring and climate coupling	Confirmed for contaminant monitoring; nuanced for climate coupling (1 included study links the performance of wastewater treatment plants to vegetation cover/climate indicators)	0 multi-year contaminant monitoring systems; 1 of the 15 included studies (Faouzi et al., 2020) links wastewater treatment plant performance to climate/vegetation indicators

DISCUSSION

The comparison between the institutional discourse on new tertiary wastewater treatment plants and the available academic literature reveals a structural discontinuity: the most robust data on soil contamination concern raw wastewater predating the new infrastructure, and no study establishes whether these facilities have reduced the documented risk. Reported progress and the scientifically documented problem therefore only partially overlap—a pattern already observed in other Mediterranean countries that have experienced a rapid acceleration of investment in wastewater reuse. Faouzi et al. (2020) represents the closest existing link between the technical and social dimensions, but predates the OCP Green Water tertiary wastewater treatment plants of 2024–2025 and cannot account for their effects.

A second tension, of a regulatory nature, deserves attention: national reuse targets are primarily agricultural, whereas the most documented actual reuse in the region is industrial, driven by a single economic actor whose investment logic differs structurally from the agricultural logic targeted by national policy. This tension has not been critically assessed in the literature consulted.

Beyond the thematic gaps, several cross-cutting methodological limitations affect the 15 included studies: a relatively small number of sampling points (typically 20 to 45 sampling points per study), a near-general absence of control groups and long time series, heterogeneous reference thresholds across studies due to the lack of a specific Moroccan standard for sludge spread on soils, and a dependence of the most recent infrastructure data on a single, unaudited institutional source chain.

CONCLUSION

This work aimed to produce a PRISMA-guided critical synthesis of the state of research on wastewater reuse and sludge valorisation in the Béni Mellal-Khénifra region, by verifying three hypothetical research gaps and proposing a priority research program. The three hypothetical gaps are largely confirmed, with two nuances: the component related to metal contamination of soil and groundwater quality is, in fact, relatively well documented locally (9 of the 15 included studies), and the governance/acceptability gap is narrowed rather than fully open, since one included study (Faouzi et al., 2020) already addresses the perceptions of farmers and

residents, although no study dedicated to institutional governance exists. Emerging contaminants, integrated antimicrobial resistance, and the agronomic valorisation of sludge remain almost entirely unexplored at the regional level.

The most significant result is the demonstrated discontinuity between the academic corpus and the institutional discourse on new infrastructure: recent tertiary wastewater treatment plants and the literature documenting historical soil contamination represent two distinct hydrological realities that remain unconnected in the published literature. Regional water managers should make institutional communication on new reuse infrastructure contingent on independent scientific monitoring, address the national regulatory gap regarding standards applicable to sludge spread on soils, and commission a study dedicated to institutional governance involving farmers in the Tadla plain and the Oum Er-Rbia River Basin Agency, building on the perception base already established by Faouzi et al. (2020).

This synthesis is limited by its reliance on online academic research rather than an export from a single proprietary database, and by the concentration of the 15 included studies within two overlapping research teams at Sultan Moulay Slimane University. The seven-axis priority research program proposed here, led by a dedicated governance study, followed by an integrated assessment of emerging contaminants and antimicrobial resistance upstream and downstream of new tertiary wastewater treatment plants, is offered as a basis for future work in this basin and in comparable Moroccan basins experiencing rapid expansion of wastewater reuse.

The limited number of studies also highlights the need for stronger collaboration between academic institutions and water-sector operators, particularly in a region where several university structures have emerged in recent years and where water management remains a central national and regional concern.

Author's statements

Contributions

Conceptualization: M.El H.; Data curation: M.El H.; Formal analysis: M.El H.; Investigation: M.El H.; Methodology: M.El H.; Supervision: S.T.; Validation: S.T.; Visualization: M.El H.; Writing – original draft: M.El H.; Writing – review & editing: M.El H., S.T.

Declaration of conflicting interest

The authors declare no competing interests.

Financial interests

The authors declare they have no financial interests.

Funding

Not applicable. The data relating to OCP Green Water infrastructure cited in this article are from secondary public sources and were neither commissioned nor funded by the OCP Group.

Data availability statement

Not applicable.

AI Disclosure

Generative AI tools were used solely for language editing and proofreading. The authors take full responsibility for the content of the manuscript, including its arguments, analysis, interpretations, and conclusions.

Ethical approval declarations

Not applicable.

Additional information

Publisher's note

Publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

REFERENCES

- Aadraoui, M., El Baghdadi, M., Rais, J., Barakat, A., Ennaji, W., Karroum, L. A., Oumenskou, H., Ouigmane, A., Mechadi, M., & Didi, S. (2018). Characteristics of sewage sludge produced from wastewater treatment plant in the Moroccan city Khouribga. *Desalination and Water Treatment*, 112, 179–185. <https://doi.org/10.5004/dwt.2018.22069>.
- Aallam, Y., El Rasafi, T., Hakkou, R., Dhiba, D., Nouri, M., Haddioui, A., & Hamdali, H. (2021). Assessing the contamination of trace toxic elements in the soils of sugar beet field (Beni-Mellal, Morocco). *Arabian Journal of Geosciences*, 14(9), 822. <https://doi.org/10.1007/s12517-021-07217-w>.
- Ait Ouhamchich, K., Arioua, A., Lbayny, M., Karaoui, I., Habbari, K. E., Idrissi, A. E. A., Hssaisoune, M., Boulli, A., Elhamdouni, D., & Elfiraoui, F. E. (2018). Performances assessment of wastewater treatment plant in Boujaâd city, Khouribga Province, Morocco. *European Scientific Journal*, 14(27), 193. <http://dx.doi.org/10.19044/esj.2018.v14n27p193>.
- Barakat, A. (2020). Groundwater NO₃ concentration and its potential health effects in Beni Moussa perimeter (Tadla plain, Morocco). *Geoenvironmental Disasters*, 7, 14. <https://doi.org/10.1186/s40677-020-00149-9>.
- Barakat, A., Ennaji, W., Krimissa, S., & Bouzaid, M. (2020). Heavy metal contamination and ecological-health risk evaluation in peri-urban wastewater-irrigated soils of Beni-Mellal city (Morocco). *International Journal of Environmental Health Research*, 30(4), 372–387. <https://doi.org/10.1080/09603123.2019.1595540>.
- Barakat, A., Mouhtarim, G., Saji, R., & Touhami, F. (2020). Health risk assessment of nitrates in the groundwater of Beni Amir irrigated perimeter, Tadla plain, Morocco. *Human and Ecological Risk Assessment: An International Journal*, 26(7), 1864–1878. <https://doi.org/10.1080/10807039.2019.1613631>.
- El Baghdadi, M., et al. (2019). Using statistical analysis to assess urban groundwater in Beni Mellal city (Morocco). *International Journal of Agronomy*, 2019, 7469741. <https://doi.org/10.1155/2019/7469741>.
- El Hamzaoui, E. H., El Baghdadi, M., Oumenskou, H., Aadraoui, M., & Hilali, A. (2020). Spatial repartition and contamination assessment of heavy metal in agricultural soils of Beni-Moussa, Tadla plain (Morocco). *Modeling Earth Systems and Environment*, 6(3), 1387–1406. <https://doi.org/10.1007/s40808-020-00756-3>.
- El Hannani, M., Nori, I., Assal, A., Kacimi, A., & Touil, S. (2026). Assessment of energy efficiency indicators for a full-scale bacterial bed in a semi-arid region: Divergence between volumetric intensity and pollutant load. *Ecological Engineering & Environmental Technology*, 27(9), 322–340. <https://doi.org/10.12912/27197050/226546>.
- Ennaji, W., Barakat, A., El Baghdadi, M., & Rais, J. (2020). Heavy metal contamination in agricultural soil and ecological risk assessment in the northeast area of Tadla plain, Morocco. *Journal of Sedimentary Environments*, 5(3), 307–320. <https://doi.org/10.1007/s43217-020-00020-9>.
- Fauzi, E., Arioua, A., Karaoui, I., Ait Ouhamchich, K., & Elhamdouni, D. (2020). Wastewater reuse in agriculture sector: Resources management and adaptation in the context of climate change: Case study of the Beni Mellal-Khenifra region, Morocco. *E3S Web of Conferences*, 183, 02005. <https://doi.org/10.1051/e3sconf/202018302005>.
- Hafiane, F. Z., Tahri, L., El Jarmouni, M., Reyad, A. M., Fekhaoui, M., Mohamed, M. O., Abdelrahman, E. A., Rizk, S. H., El-Sayyad, G. S., & Elkhatab, W. F. (2024). Incidence, identification and antibiotic resistance of Salmonella spp. in the well waters of Tadla plain, Morocco. *Scientific Reports*, 14, 15380. <https://doi.org/10.1038/s41598-024-61917-3>.
- Hilali, A., El Baghdadi, M., & El Hamzaoui, E. H. (2021). GIS and AHP multi-criteria analysis methods for the quality assessment of agricultural soils irrigated with wastewater: Case of the Day River, Beni Mellal (Morocco). *Arabian Journal of Geosciences*, 14, 2388. <https://doi.org/10.1007/s12517-021-08654-3>.
- Hilali, A., El Baghdadi, M., & Halim, Y. (2022). Environmental monitoring of heavy metals distribution in the agricultural soil profile and soil column irrigated with sewage from the Day River, Beni-Mellal City (Morocco). *Modeling Earth Systems and Environment*, 9, 1859–1872. <https://doi.org/10.1007/s40808-022-01592-3>.
- Hilali, A., El Baghdadi, M., Barakat, A., Ennaji, W., & El Hamzaoui, E. H. (2020). Contribution of GIS techniques and pollution indices in the assessment of metal pollution in agricultural soils irrigated with wastewater: Case of the Day River, Beni Mellal (Morocco). *Euro-Mediterranean Journal for Environmental Integration*, 5(3), 52. <https://doi.org/10.1007/s41207-020-00186-8>.
- Kingdom of Morocco. (2002). *Joint Decree No. 1276-01 of October 17, 2002, establishing the quality standards for water intended for irrigation. Official Bulletin*, 5062.
- Kingdom of Morocco. (2016). *Royal Decree No. 1-16-113 of August 10, 2016, promulgating Law No. 36-15 relating to water. Official Bulletin*, 6506.
- Ministry of Energy Transition and Sustainable Development. (2025). *Statements relating to obstacles to the valorization of sewage sludge* [Government statement, Kingdom of Morocco].
- Oumenskou, H., El Baghdadi, M., Barakat, A., Aquit, M., Ennaji, W., Karroum, L. A., & Aadraoui, M. (2018). Assessment of the heavy metal contamination using GIS-based approach and pollution indices in agricultural soils from Beni Amir irrigated perimeter, Tadla plain, Morocco. *Arabian Journal of Geosciences*, 11(22), 692. <https://doi.org/10.1007/s12517-018-4021-5>.
- Soudi, B., & El Khoumsi, W. (2024). *Management and agricultural valorization of sewage sludge in Morocco* [Report]. FAO Sub-regional Office for North Africa. https://bdd.pseau.org/outils/ouvrages/fao_gestion_et_valorisation_agricole_des_boues_d_epuration_au_maroc_rapport_national_maroc_2024.pdf.
- Talbi, N., Rouhi, A., Merzouki, M., & Merzouki, H. (2025). Evaluation of trace metal element concentrations in sediments from sites receiving treated wastewater inputs in the Beni Mellal-Khenifra region, Morocco. *Journal of Ecological Engineering*, 26(9), 205–217. <https://doi.org/10.12911/22998993/205109>.