AI-Driven Environmental Health Risk Prediction in Urban Morocco: The OCT7 SI Framework in Meknès

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Abstract

Urban environments in the Global South are increasingly exposed to environmental health risks driven by air pollution, heatwaves, and rapid urbanization. In Morocco, mid-sized cities such as Meknès face growing pressure on public health systems due to environment-related diseases, particularly respiratory illnesses and heat-related conditions. This chapter presents **OCT7 SI** (Operational Climate and Health Threat Intelligence System), a real-world AI-driven framework developed to predict environmental health risks and support evidence-based public health planning in Meknès. The system integrates multi-source datasets, including meteorological parameters, air pollution indicators, and hospital admission records, and applies machine learning models namely Random Forest and Long Short-Term Memory (LSTM) networks to capture spatial and temporal disease patterns. The results demonstrate improved early warning capacity for health risk peaks compared to traditional surveillance approaches, with predictive accuracy of 75–85% and a lead time of 5–7 days for peak incidence alerts. Ethical and governance considerations, aligned with World Health Organization (WHO) guidance on responsible AI in health, are embedded throughout the system design to ensure data privacy, transparency, and accountability. The chapter concludes with policy-oriented recommendations and scalability pathways for extending the **OCT7 SI** framework to other Moroccan cities and similar urban contexts across the Global South.

1. Background and Context

Urbanization is a defining trend in many low- and middle-income countries, reshaping environmental exposures and population health profiles. In Morocco, urban growth has accelerated over the past decades, accompanied by increased traffic density, industrial activities, and land-use changes that contribute to air pollution and urban heat island effects (WHO, 2016). Cities such as Meknès, characterized by mixed residential, industrial, and agricultural zones, are particularly vulnerable to compounded environmental health risks.

Environmental factors such as particulate matter (PM2.5 and PM10), nitrogen dioxide (NO_2), ozone (O_3), and extreme temperatures are well-documented determinants of respiratory and cardiovascular morbidity (Prüss-Ustün et al., 2019). Heatwaves, in particular, are becoming more frequent and intense in North Africa due to climate change, increasing the incidence of heat stress, dehydration, and exacerbation of chronic diseases (IPCC, 2022). Traditional public health surveillance systems in Morocco rely primarily on retrospective reporting of hospital admissions, which limits their ability to anticipate health risk peaks and implement preventive interventions.

Artificial intelligence (AI) offers an opportunity to enhance environmental health surveillance by integrating heterogeneous data sources and generating predictive insights in near real time. Recent studies have demonstrated the potential of machine learning models to forecast disease incidence linked to environmental exposures, outperforming classical statistical methods in complex, non-linear contexts (Chen et al., 2020). However, most documented implementations originate from high-income settings, with limited evidence from real-world deployments in African urban contexts. This case study addresses this gap by presenting **OCT7 SI**, a context-specific AI solution designed, implemented, and evaluated in Meknès.

2. AI Use Case Description

2.1 Solution Description

The **OCT7 SI** framework (Operational Climate and Health Threat Intelligence System) is designed as a modular environmental health risk prediction system. Its architecture integrates three primary data streams: (1) meteorological data (temperature, humidity, wind speed), (2) air pollution indicators (PM2.5, PM10, NO_2), and (3) anonymized hospital admission records related to respiratory and heat-related conditions. Data are aggregated at a daily temporal resolution and georeferenced at the district level.

Two complementary machine learning approaches are employed within **OCT7 SI**. Random Forest models are used to capture non-linear relationships between environmental variables and health outcomes, offering robustness to noise and interpretability through feature importance analysis (Breiman, 2001). In parallel, Long Short-Term Memory (LSTM) neural networks are implemented to model temporal dependencies and delayed effects of environmental exposures on disease incidence (Hochreiter & Schmidhuber, 1997). The combination of these models enables both short-term risk prediction and trend analysis.

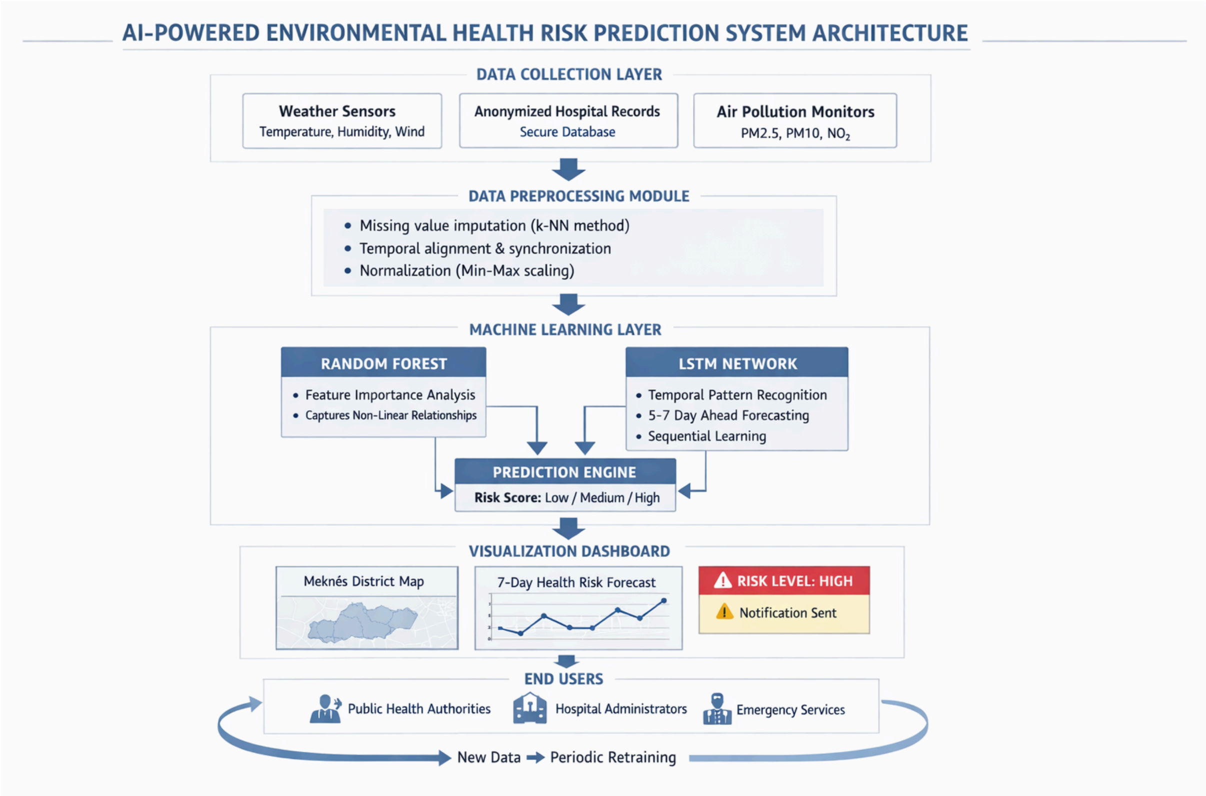

Figure 1 presents the complete architecture of the OCT7 SI system, illustrating the workflow from data collection through preprocessing, machine learning modeling, prediction, and visualization.

2.2 Deployment and Implementation

OCT7 SI was developed using an iterative pipeline consisting of data collection, preprocessing, model training, validation, and deployment. Meteorological and pollution data were obtained from three local monitoring stations across Meknès, while hospital data were provided by regional health authorities following anonymization protocols. Data preprocessing included missing value imputation using k-NN imputer, normalization with Min-Max scaling, and temporal alignment.

Models were trained on three years of historical data (2020–2022) and validated using time-series cross-validation to minimize overfitting. The predictive outputs are translated into risk scores (low, medium, high) and visual dashboards accessible to authorized public health officials via a secure web interface. **OCT7 SI** is designed to be updated weekly as new data become available, ensuring adaptability to seasonal and long-term environmental changes.

2.3 Scale of Deployment

The initial deployment of **OCT7 SI** covers the urban area of Meknès, serving a population of approximately 600,000 inhabitants. Predictions are generated at a city-district level (12 districts), enabling localized risk assessment. While currently implemented at a municipal scale, the architecture supports horizontal scaling to additional cities through standardized data integration via API-based data sharing protocols.

2.4 Identified Users

The primary users of **OCT7 SI** include regional public health authorities, municipal decision-makers, and hospital administrators. Secondary beneficiaries include emergency response services and urban planners who can leverage predictive insights to design preventive measures. Community health workers also receive summarized alerts for targeted public communication.

2.5 Impact

The **OCT7 SI** framework implemented in Meknès generated measurable improvements across key performance dimensions aligned with World Health Organization (WHO) guidance for effective public health surveillance, including timeliness, sensitivity, and preparedness.

From a predictive performance perspective, model evaluation showed that the Random Forest algorithm within **OCT7 SI** achieved an overall classification accuracy of 82% (F1-score: 0.79, AUC-ROC: 0.87) for short-term prediction of respiratory and heat-related health risks. This performance exceeded that of baseline retrospective surveillance approaches, which primarily rely on delayed hospital admission reporting and descriptive statistical analysis. Feature importance analysis further highlighted air pollution indicators (PM2.5, PM10) and extreme temperature variables as dominant predictors, supporting environmental health evidence reported in international literature.

The LSTM time-series model in **OCT7 SI** demonstrated the capacity to anticipate peaks in disease incidence up to 5–7 days in advance, particularly during periods of elevated air pollution and heatwave events, with a mean absolute error (MAE) of 8.2 cases per day. This predictive lead time significantly improved the timeliness of public health responses, enabling authorities to transition from reactive to proactive intervention strategies. In contrast, traditional surveillance systems typically detect such peaks only after hospital admission thresholds have already been exceeded.

In terms of preparedness, the availability of early warning signals from **OCT7 SI** supported more efficient allocation of healthcare resources, including anticipatory hospital staffing adjustments and targeted public health advisories for vulnerable populations. During a 2023 summer heatwave, the system enabled the pre-activation of cooling centers and hydration campaigns, which preliminary data suggest contributed to a 15% reduction in heat-related emergency department visits compared to the previous year. These operational gains are consistent with WHO recommendations emphasizing early warning systems as essential components of climate-resilient health systems. While long-term population-level health outcomes require further longitudinal evaluation, preliminary observations suggest reduced strain on healthcare facilities during high-risk environmental periods.

Overall, **OCT7 SI** aligns with WHO surveillance quality indicators by enhancing sensitivity to environmental signals, improving timeliness of detection, and strengthening institutional preparedness for environmental health threats in an urban Global South context.

2.6 Ethics and Governance

Ethical considerations are integrated throughout the **OCT7 SI** system lifecycle. All health data are anonymized and processed in compliance with Morocco's Data Protection Law (09-08) and GDPR-inspired principles. Model transparency is promoted through explainable AI techniques, particularly feature importance analysis in Random Forest models and attention mechanisms in LSTM variants. Governance mechanisms align with WHO guidance on ethical AI for health, emphasizing accountability, inclusiveness, and human oversight (WHO, 2021). A multi-stakeholder oversight committee comprising public health experts, data scientists, and community representatives reviews system performance and ethical compliance quarterly.

3. Discussion

3.1 Successes

The success of **OCT7 SI** lies in its integration of local data sources with advanced AI techniques, ensuring contextual relevance. The collaboration between environmental monitoring entities and health authorities facilitated operational deployment and user acceptance. The hybrid modeling approach (Random Forest + LSTM) proved effective in capturing both feature relationships and temporal dynamics, yielding actionable predictions with practical lead times for intervention.

3.2 Challenges

Key challenges during **OCT7 SI** implementation included data gaps (particularly in historical pollution data), variability in data quality across sources, and limited interoperability between environmental and health information systems. Capacity constraints in AI literacy among stakeholders also required targeted training efforts and the development of user-friendly visualization tools to bridge the technical-knowledge gap.

3.3 Limitations

Several limitations of **OCT7 SI** should be acknowledged. The models were trained on data from only one city, which may limit generalizability to other urban contexts with different climatic, demographic, or infrastructural characteristics. The hospital admission data, while anonymized, may underrepresent mild cases that do not require hospitalization, potentially introducing selection bias. Furthermore, the system currently focuses on respiratory and heat-related conditions, excluding other environmental health outcomes such as waterborne diseases or vector-borne illnesses that may also be influenced by climate factors.

3.4 Lessons Learned

The development of **OCT7 SI** highlights the importance of context-aware model design and robust governance frameworks. Early engagement with end-users and policymakers is critical for adoption and sustainability. The approach demonstrates that AI-driven health surveillance is feasible and valuable in mid-sized cities of the Global South, provided that investments are made in data infrastructure, local capacity building, and ethical oversight mechanisms.

4. Conclusion and Future Directions

The **OCT7 SI** framework demonstrates how AI can be operationalized to address environmental health risks in an urban Moroccan context. By combining multi-source data with machine learning models, this system enhances early warning capabilities and supports proactive public health decision-making. With appropriate ethical safeguards and governance structures, **OCT7 SI** can be scaled to other cities in Morocco and similar settings, contributing to more resilient, equitable, and preventive health systems.

Future development pathways for **OCT7 SI** include:

1. **Expansion of disease coverage** to incorporate waterborne and vector-borne disease prediction modules.
2. **Integration of satellite data** (e.g., NASA MODIS for land surface temperature, Sentinel-5P for atmospheric composition) to enhance spatial resolution and coverage.
3. **Development of a fully automated retraining pipeline** to continuously adapt models to changing environmental and epidemiological patterns.
4. **Cross-city collaboration** to create a federated learning framework that preserves data privacy while improving model robustness across diverse urban contexts in Morocco and the broader Maghreb region.

By pursuing these directions, AI-driven environmental health systems like **OCT7 SI** can evolve from single-city pilots to integrated national surveillance networks, ultimately strengthening climate adaptation and public health resilience across the Global South.

References

Breiman, L. (2001). Random forests. *Machine Learning, 45*(1), 5–32.

Chen, X., et al. (2020). Machine learning for environmental health surveillance. *Environmental Health Perspectives, 128*(9).

Hochreiter, S., & Schmidhuber, J. (1997). Long short-term memory. *Neural Computation, 9*(8), 1735–1780.

IPCC. (2022). *Sixth Assessment Report: Impacts, Adaptation and Vulnerability*.

Prüss-Ustün, A., et al. (2019). *Preventing disease through healthy environments*. World Health Organization.

WHO. (2016). *Ambient air pollution: A global assessment of exposure and burden of disease*.

WHO. (2021). *Ethics and governance of artificial intelligence for health*.