

Architecture for Real-Time Air Quality Monitoring and Personalized Health Recommendations in Bogotá

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Air pollution is a critical public health challenge. This work presents a production-ready architecture for **real-time air quality monitoring in Bogotá** that integrates heterogeneous data sources (AQICN, Google Air Quality API, IQAir) into a unified 3NF PostgreSQL schema with sub-100 millisecond query latencies and personalized health recommendations.

Primary Goal: Design and validate a production-ready architecture integrating multi-source air quality data with normalized schema and personalized health recommendations.

Specific Objectives:

1. Integrate AQICN, Google, & IQAir with 216 readings/hour via Python APScheduler
2. Implement 3NF PostgreSQL schema (8 entities) with temporal partitioning
3. Achieve sub-100ms query latencies across 85,000+ readings
4. Support 50–100 concurrent users with documented concurrency mitigation
5. Deliver rule-based health recommendations per EPA/WHO AQI standards

8 Normalized Entities:

Database Schema - 8 Entities (3NF)		
Geospatial & Monitoring		
Station	Pollutant	Provider
AirQualityReading	AirQualityDailyStats	
Users & Access		
AppUser	Alert	Recommendation
Key Features:		
<ul style="list-style-type: none">• Monthly partitioning (85K+ readings)• Composite B-tree indexes• Materialized views (35× reduction)• Referential integrity constraints		

Relational schema with referential integrity, monthly partitioning, and composite indexes

Key Features:

- **Temporal Partitioning:** Monthly tables for 78% latency improvement
- **Materialized Views:** 35× row reduction (85K → 2.4K)
- **Composite Indexes:** B-tree on (station, pollutant, datetime)
- **MVCC Isolation:** Zero-downtime concurrent reads/writes

Scalability & Performance

Current Performance:

50-100 concurrent users
70-75% CPU usage
Sub-150ms latency
140 req/sec throughput

Scaling Strategies:

Vertical: 8+ vCPUs → 1,000+ users
Horizontal: Read replicas + Load balancer
Partitioning: Monthly tables (78% improvement)

10-Year Projection:

525M+ readings
Partition pruning
Consistent sub-200ms latency

Current Capacity:

- 50–100 concurrent users (70–75% CPU)
- 140 requests/second throughput
- Sub-150ms latency at 500 users

Scaling Strategies:

- **Vertical:** 8+ vCPUs → 1,000+ users
- **Horizontal:** Read replicas + load balancer
- **Partitioning:** 78% latency improvement (10-year projection)