**Final Report: Effect of Air Quality on Sleep Patterns in Istanbul**

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1. **Introduction**

This study examines the relationship between air pollution in Tuzla, Istanbul, and personal sleep patterns over a three-month period (March 14 - May 12, 2024). By integrating publicly available air quality data with personal sleep metrics, this research explores how pollutants like PM2.5, CO, and NO₂ impact sleep duration and quality. The project combines data collection, statistical analysis, and machine learning to provide actionable insights for urban residents.

**2. Methodology**

**2.1 Data Collection and Preparation**

* **Air Quality Data**: Daily measurements (PM2.5, PM10, NO₂, SO₂, CO, O₃) sourced from:
  + Istanbul Hava Kalitesi İzleme Merkezi
  + IQAir (Tuzla station)
* **Sleep Metrics**: Recorded via sleep tracking app:
  + Sleep duration (hours)
  + Sleep quality (0-100 scale)
  + Time-to-sleep (minutes)
* **Cleaning**:
  + Removed outliers in PM10, O₃, SO₂, and sleep metrics using IQR method
  + Handled 0 missing values across 35 days
* **Feature Engineering**:
  + is\_weekend: Binary flag for weekends
  + CO\_log/PM2.5\_log: Log-transformed pollutants for reducing skewness
  + good\_sleep: Binary target (1 if sleep quality > 60, 0 otherwise)

**2.2 Analytical Approach**

1. **Descriptive Statistics**: Central tendencies and spreads of key variables.

| **Variable** | **Mean** | **Std Dev** | **Range** | **Distribution** |
| --- | --- | --- | --- | --- |
| PM2.5 (µg/m³) | 20.55 | 7.06 | 8.7-36.1 | Right-skewed |
| CO (µg/m³) | 408.6 | 184 | 123-886 | Normal |
| Sleep Quality | 63.29 | 15.39 | 27-92 | Bimodal |
| Sleep Duration (hr) | 6.90 | 0.95 | 5.1-9.1 | Normal |

1. **Hypothesis Testing**:
   * T-tests (e.g., weekend vs. weekday sleep)
   * Pearson correlations (pollutants vs. sleep metrics)

**H₀**: Air quality doesn't affect sleep quality → **Rejected**

CO negatively correlated with sleep quality (r = -0.51, p=0.002)

**H₀**: Weekend sleep ≠ Weekday sleep → **Not rejected**

t = 0.68, p = 0.507

* + CO showed strongest sleep impact (r = -0.51)
  + PM2.5 has the secondary influence (r = -0.43)
  + O3 and NO₂ negligible effects ( -0.2 < r < 0.2)

1. **Machine Learning**:
   * Classification models to predict good sleep which is quality > 60.
   * Algorithms: Logistic Regression, Random Forest, SVM

**3. Key Findings**

3.1 Descriptive Statistics

|  |  |  |
| --- | --- | --- |
| Model | Hyperparameters | Strengths |
|  |  |  |  |
| **Logistic Regression** | penalty='l2', C=0.1 | Interpretability |
| **Random Forest** | N estimators=100, max depth=3 | Non-linear patterns |
| SVM | kernel='linear', C=0.5 | High-dimensional spaces |

3.2 Critical Relationships

* **CO vs. Sleep Quality**: Strong negative correlation (r = -0.51, p=0.002)
* **Threshold Effect**: Days with CO > 400 µg/m³ showed 48% lower sleep quality (p=0.03)
* **Weekend Effect**: No significant difference in sleep duration (p=0.51)

3.3 Machine Learning Results

Model Performance Comparison

| **Model** | **Accuracy** | **Precision** | **Recall** | **F1-Score** | **AUC** |
| --- | --- | --- | --- | --- | --- |
| Logistic Regression | 72.7% | 75.0% | 85.7% | 80.0% | 0.86 |
| Random Forest | 81.8% | 77.8% | 100% | 87.5% | 0.89 |
| SVM | 54.5% | 62.5% | 71.4% | 66.7% | 0.84 |

**Confusion Matrices:**

**Logistic Regression**: TP=6, FP=2, FN=1, TN=3

**Random Forest**: TP=7, FP=2, FN=0, TN=3

**SVM**: TP=5, FP=3, FN=2, TN=2

**Logistic Regression Coefficients**

| **Feature** | **Coefficient** | **Impact on Sleep Odds** |
| --- | --- | --- |
| **CO\_log** | -0.329 | 28% ↓ per log-unit for good sleep |
| **PM2.5\_log** | -0.325 | 28% ↓ per log-unit for good sleep |
| **is\_weekend** | -0.040 | Negligible effect |

**Confusion Matrix Insights**:

* Random Forest achieved perfect recall (100%), identifying all "good sleep" days
* SVM struggled with class imbalance (more "good sleep" days)
* Random Forest (AUC=0.89) showed superior class separation

**5. Actionable Recommendations**

1. **Critical Thresholds**:
   * Use air purifiers when CO > 400 µg/m³ or PM2.5 > 35 µg/m³
   * Limit outdoor activity during mid-week pollution peaks
2. **Sleep Optimization**:
   * Pre-sleep routines on high pollution days
   * Humidity control (optimal: 40-60%)
3. **Policy Implications**

* Stricter emission controls near Tuzla industrial zones
* Real-time public health alerts using Random Forest model
* Urban green space development in residential areas

**4. Limitations and Future Work**

4.1 Constraints

* **Small Dataset**: 3-month dataset
* **Uncontrolled Confounders**: Stress, diet, and screen time not tracked
* **Geographic Specificity**: Results apply to Tuzla, Istanbul

4.2 Future Directions

1. **Longitudinal Tracking**: 6-12 months of data to capture seasonal trends
2. **Wearable Integration**: Add heart rate variability and movement metrics
3. **Advanced Modeling**:
   * LSTM networks for temporal patterns
4. **Real-time Alert System**: Mobile app using Random Forest predictions

**5. Conclusion**

This study demonstrates that **carbon monoxide (CO)** and **PM2.5** significantly disrupt sleep quality in urban environments. Key takeaways:

1. **Critical Thresholds**: CO > 400 µg/m³ or PM2.5 > 35 µg/m³ substantially increase poor sleep risk (by 28%).
2. **Model Superiority**: Random Forest (F1=87.5%) outperformed other classifiers, making it suitable for real-time alerts.
3. **Policy Implications**: Stricter emission controls near industrial zones could improve public health.

These findings and the project bridge personal wellness and environmental science, highlighting how data-driven approaches can address urban health challenges. Future work should expand data collection and integrate physiological metrics for refined insights.