Insights into wet deposition of trace elements to central Himalayas: Spatial and seasonal variations

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ACAM-2017- Guangzhou

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Sources and transport pathways of pollutants in the environment
Precipitation composition studies

Why??

- Precipitation is considered as the natural pathway for removal of atmospheric pollutants
- Data of the wet deposition of trace elements are useful for assessment of pollutant emission
  - Bioaccumulation
  - Toxic and risk to human and the ecosystem health
  - Persistence and can be long-range transported
Mercury???

- High toxicity, volatility
- Long range transport
- Long atmospheric residence
- Bio-accumulate in human body

**MERCURY HEALTH EFFECTS**

- Deteriorates nervous system
- Impairs hearing, speech, vision and gait
- Causes involuntary muscle movements
- Corrodes skin and mucous membranes
- Causes chewing and swallowing to become difficult
Status in southern side of the central Himalayas

- Lack of studies
- Long term monitoring
Objectives

Long term Observation: Inorganic Elements and Hg

- Understand the distribution, seasonality and sources of inorganic pollutants
- Baseline database
Sampling sites

- Kathmandu, Dhunche, Dimsa and Gosainkunda on the southern side of central Himalayas.

- Urban, semi-urban and rural with different elevation transect and geographical features

### Stations sites, elevation and average annual rainfall

<table>
<thead>
<tr>
<th>Sites</th>
<th>Latitude (°N)</th>
<th>Longitude (°E)</th>
<th>Altitude (m)</th>
<th>Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kathmandu</td>
<td>27.68</td>
<td>85.35</td>
<td>1314</td>
<td>1445.22</td>
</tr>
<tr>
<td>Dhunche</td>
<td>28.11</td>
<td>85.30</td>
<td>2065</td>
<td>1883.92</td>
</tr>
<tr>
<td>Dimsa</td>
<td>28.10</td>
<td>85.33</td>
<td>3078</td>
<td>-</td>
</tr>
<tr>
<td>Gosainkunda</td>
<td>28.08</td>
<td>85.40</td>
<td>4417</td>
<td>-</td>
</tr>
</tbody>
</table>
Sampling sites

The major human activities around the Kathmandu are vehicles emission, industries, unmanaged urbanization and agricultural activities around the valley.

In Dimsa and Gosainkunda, the major human activities are tourism and limited agricultural activities, local emissions are only due to burning of biomass for cooking and making the houses warm.
Sampling Sites

- Langtang National park
- Capital city
- 15Km
- Tibetan Plateau
Laboratory analysis

- Inductively coupled plasma-mass spectrometry (ICP-MS, X-7 Thermo Elemental)
- Trace elements (e.g. Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, and Pb)

- Mercury: cold and vapor atomic fluorescence spectroscopy (CVAFS)
- Tekran (Model 2600 mercury analysis system)
### Results: concentration of elements in Precipitation

<table>
<thead>
<tr>
<th>Element</th>
<th>Kathmandu N=68</th>
<th>Dhunche N=69</th>
<th>Dimsa N=45</th>
<th>Gosainkuna N=40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>145.05</td>
<td>52.25</td>
<td>84.71</td>
<td>40.36</td>
</tr>
<tr>
<td>Cr</td>
<td>1.11</td>
<td>0.20</td>
<td>1.06</td>
<td>0.95</td>
</tr>
<tr>
<td>Mn</td>
<td>5.76</td>
<td>2.25</td>
<td>4.67</td>
<td>2.08</td>
</tr>
<tr>
<td>Fe</td>
<td>170.58</td>
<td>52.49</td>
<td>85.44</td>
<td>43.41</td>
</tr>
<tr>
<td>Co</td>
<td>0.69</td>
<td>0.38</td>
<td>1.18</td>
<td>0.79</td>
</tr>
<tr>
<td>Ni</td>
<td>0.49</td>
<td>1.02</td>
<td>1.03</td>
<td>0.47</td>
</tr>
<tr>
<td>Cu</td>
<td>1.35</td>
<td>0.87</td>
<td>0.92</td>
<td>0.45</td>
</tr>
<tr>
<td>Zn</td>
<td>16.91</td>
<td>9.78</td>
<td>8.40</td>
<td>13.15</td>
</tr>
<tr>
<td>Cd</td>
<td>0.071</td>
<td>0.061</td>
<td>0.018</td>
<td>0.01</td>
</tr>
<tr>
<td>Pb</td>
<td>0.981</td>
<td>0.908</td>
<td>0.589</td>
<td>0.357</td>
</tr>
</tbody>
</table>

- Higher mineral particle loading in urban site (Kathmandu)
- Cd and Pb showed a trend “higher/lower in south/north”
- Kathmandu was not clear
- Local sources were dominant over the regional sources
- Other three stations exhibited a clear seasonal variation
Enrichment Factor: Natural crustal Vs anthropogenic contribution

The EF can be defined as:

\[ EF_x = \frac{(C_x/C_R)_{\text{precipitation}}}{(C_x/C_R)_{\text{soil}}} \]

- Where \( X \) represents the element of interest
- \( EF_x \) is the enrichment factor of \( X \); \( C_x \) is the concentration of \( X \); and \( C_R \)
- The concentration of a reference element (e.g. Al)

- The average top soil composition from the Tibetan Plateau (Li et al., 2009)
- Proximity of our sampling sites with the TP
Average Enrichment Factors of Trace elements

- Non-enriched elements such as (Fe, Mn; 1-10)
- Moderately enriched such as (Cr, Ni, Cu and Pb; 10-100)
- Highly enriched (Cd and Zn; >100)
EFs vs. log Al

- EF of non-crustal elements would decrease with increasing Al concentration

- Fe and Mn do not show good correlations

- Remaining elements have a more defined inverse relationship, indicating a source other than crustal.
## Results: Mercury in precipitation

<table>
<thead>
<tr>
<th>Sites</th>
<th>THg (ng L⁻¹)</th>
<th>RHg/THg (%)</th>
<th>PHg/THg (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kathmandu</td>
<td>20.6</td>
<td>20</td>
<td>59</td>
</tr>
<tr>
<td>Dhunche</td>
<td>10.1</td>
<td>26</td>
<td>60</td>
</tr>
<tr>
<td>Dimsa</td>
<td>7.7</td>
<td>19</td>
<td>80</td>
</tr>
<tr>
<td>Gosainkunda</td>
<td>6.5</td>
<td>5</td>
<td>63</td>
</tr>
</tbody>
</table>

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**Kathmandu**

- RHg/THg: 20%, $R^2 = 0.34$, $p = 0.05$
- PHg/THg: 59%, $R^2 = 0.73$, $p < 0.05$

- RHg/THg: 27%, $R^2 = 0.50$, $p = 0.05$
- PHg/THg: 71%, $R^2 = 0.93$, $p < 0.05$

**Dhunche**

- RHg/THg: 19%, $R^2 = 0.72$, $p = 0.05$
- PHg/THg: 81%, $R^2 = 0.87$, $p < 0.05$

- RHg/THg: 5%, $R^2 = 0.93$, $p < 0.05$
- PHg/THg: 63%, $R^2 = 0.93$, $p < 0.05$

**Dimsa**

- RHg/THg: 19%, $R^2 = 0.72$, $p = 0.05$
- PHg/THg: 81%, $R^2 = 0.87$, $p < 0.05$

**Gosainkunda**

- RHg/THg: 5%, $R^2 = 0.93$, $p < 0.05$
- PHg/THg: 63%, $R^2 = 0.93$, $p < 0.05$
Seasonal variations of total Mercury

Monsoon
Enrichment of Mercury in precipitation
Conclusions

• Elemental composition mainly controlled by regional crustal dust and anthropogenic emissions

• Elements (Cr, Co, Ni, Cu, Zn, Cd, Pb and Hg) were from anthropogenic sources and Al, Fe and Mn were from crustal origin

• Major anthropogenic metals had decreasing trend from urban to remote and lower to higher altitude

• No clear seasonal variation at urban location

• Remote sites are still ideal place to monitor background concentrations

• Baseline database established

• Need for more long-term spatial monitoring to better understand the long-range transport of pollutants from South Asia and other regions to Himalayas
Thank you