Natural Wetlands Treatment of Sewage Discharges from Phnom Penh, Cambodia: Successes and Future Challenges

Kim N. Irvine, Buffalo State, State University of New York
Wetlands Treatment Increasingly Accepted Throughout the World
Constructed Wetland for Industrial Park, Rayong, Thailand
AIT - An Important Regional Resource for Wetlands Studies
Phnom Penh is Growing and Developing
Background to Study

- City of Phnom Penh serviced by a combined sewer system, with ~160 km of concrete sewer pipe ranging in diameter from 0.3-1.5 m.

- Concrete sewers discharge to larger open channels that are connected via pumping stations to the treatment wetlands that ring the city.
Peri-urban agriculture
Primary Objective: *Determine How Effective Phnom Penh’s Current Wetland Configuration is in Sustainably Treating Sewage Discharge*
Principal Team Members

Va Dany
Yim Mongtoeun
Kok Sothea
Chea Eliyan
Saneth Vathna
Tiev Visoth
Sovann Channsopheaktra
Im Nara

Department of Environmental Science, Royal University of Phnom Penh

Ratchadawan Ngoen Klan
Department of Parasitology, Faculty of Medicine, Chiang Mai University
Team Coordination and Additional Collaboration

Thammarat Koottatep – Asian Institute of Technology, Team Coordinator

Kim Irvine – Buffalo State, State University of New York, Team Mentor

Mickey Sampson and Ung Mengieng, Resource Development International – Cambodia

Doug Graber Neufeld, Eastern Mennonite University and Royal University of Phnom Penh

Thong Sokvongsa, Bun Kla, Ministry of Environment

Juha Sarkkula and Matti Kummu, MRC WUP-FIN (Mekong River Commission, Water Utilization Program – Finland)

Drs. K and K. Sukontason, Chiang Mai University

10 undergraduate students from Royal University of Phnom Penh, as well as undergraduate and graduate students from Buffalo State, AIT, and Chiang Mai University
Analytes of Interest

- E. coli
- O. viverrini
- Cr
- Cu
- Zn
- Nitrates
- Total phosphorus
- Dissolved oxygen
- pH
- Temperature
- Conductivity
- Turbidity
- Total suspended solids
- Detergents
- Flow
Sample Locations
Sampling Trabek Channel
Sampling Meancheey Channel
Sampling in Boeng Cheung Ek
Installation of YSI Continuous Monitoring Units
Cambodian effluent standards for protected public water areas: Cr – 50 μg/L
Cambodian effluent standards for protected public water areas: Cu – 200 μg/L
Mean Dry Weather Results, 14 Sample Dates, 3/30/07-4/20/08
Geometric Mean E. coli for dry weather samples, dry seasons, 3/30/07-4/20/08, n=14 (left)

WHO standard, unrestricted irrigation for crops eaten raw – 1,000 E. coli/100 mL

Mean detergents levels for dry weather samples, dry seasons, 3/30/07-4/20/08, n=14 (right)

Cambodian standard – 5 mg/L
Results of Spatially-Intensive Sampling, 2008
Dye Testing Near Trabek Pump Station, November 2007
Intensive Sample Collection in Boeng Cheung Ek, 2008

- 58 samples were collected between April 22 and 25, 2008 for E. coli analysis
- 45 samples were collected between June 4 and 6, 2008 for E. coli and detergents analysis
Innovative Sampling
E. coli Results, June, 2008

Sampling

E. coli were reduced by 99.9% within 200 m from the point of entry to the wetland.

Flow travels approximately another 2,500 m before it reaches the Middle sample site.

Small increases in E. coli were recorded at some of the further sample sites due to discharges from local homes and factories.
E. coli Results, April, 2008

Sampling

The E. coli levels entering the wetland were higher for the April sampling, at around $6.1 \times 10^6/100\ mL$ (compared to $3.8 \times 10^6/100\ mL$ in June)

It took approximately 350 m to observe a 99.5% decrease in levels
Detergents (anionic surfactants)  
Results, June, 2008 Sampling

Detergents levels were reduced by 87% within 200 m from the point of entry to the wetland.

Small increases in detergents levels were recorded at some of the further sample sites due to local discharges.

The primary industrial activity in Phnom Penh is textiles and anionic surfactants are used in various processes including cleaning, cotton desizing, and dye dispersant.
Additional Observations

April and June results generally are consistent, as a progressive decrease in E. coli level occurred prior to the flow reaching the Middle site.

Based on all 2007 and 2008 sample results, the geometric mean level of E. coli was in the range of 275-3,409/100 mL by the mid-point of the wetland.

This range of E. coli meets or nearly meets the level of 1,000/100 mL recommend by WHO (2006) as the maximum for unrestricted irrigation of crops eaten raw.
Wet Weather vs. Dry Weather
Mean Dry Weather Values vs. Average EMC

\( n = 14 \) for mean dry weather values; \( n = 8 \) for average EMC; \( D = \text{Different}, \alpha = 0.05 \)
Trabek Channel, Dry Weather

Trabek Channel, Wet Weather
Cool Things We Can See with the YSIs
Dissolved Oxygen Dynamics

JICA, 1999 – sewer d.o. – 0.1-4.6 mg/L; Irvine et al., 2007 – 1.5-2.0 mg/L; MOE, 2003/2004 – 1.7-2.1 mg/L

D.O., mg/L

Time, 15 minute steps, 2007

Meanin  Outlet
Weekly Mean YSI Results, Outlet Site

Cond. mS/cm

D.O., mg/L


Cond.

D.O.
Other Analyses
PCSWMM.NET Model of Sewer System and Wetland

- Meanchevy and Trabek sewersheds divided into 52 sub-catchments for modeling in PCSWMM.NET
- Three design storms examined, small (27 mm), medium (77 mm) and large (392 mm) events
- Storms were 1-3 hours in duration and had exceedance probabilities of 10%, 2.8% and 0.0002%, respectively
Design Storms and Duration of Surface Flooding

Duration of low and medium storm corresponds to left axis.
Surface Flooding in Phnom Penh
## Contaminant Mass Loading Estimates for Large Modeled Storm

<table>
<thead>
<tr>
<th>Location</th>
<th>Mass Loading (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cr</td>
</tr>
<tr>
<td>Meanchey</td>
<td></td>
</tr>
<tr>
<td>Up</td>
<td>16.57</td>
</tr>
<tr>
<td>Trabek</td>
<td></td>
</tr>
<tr>
<td>Down</td>
<td>16.44</td>
</tr>
</tbody>
</table>

Cu and Cr loads above are of the same order of magnitude as an entire month of dry weather flow. Nitrate and phosphorus loadings were much smaller than a month of dry weather flow due to stormwater dilution.
Fishing in Boeng Cheung Ek
<table>
<thead>
<tr>
<th>Fish Species</th>
<th>Weight of fish (g)</th>
<th>Number of found metacercariae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jullien’s mud carp <em>Cirrhina jullieni</em></td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>Indian river barb <em>Cyclocheilichthys apagon</em></td>
<td>683</td>
<td>56</td>
</tr>
<tr>
<td>Moonlight gourami <em>Trichogaster microlepis</em></td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>Red-cheek barb <em>Hampala dispers</em></td>
<td>430</td>
<td>171</td>
</tr>
<tr>
<td>Giant featherback <em>Chitala lopis</em></td>
<td>161</td>
<td>0</td>
</tr>
<tr>
<td>Smith barb <em>Puntioplites protozysron</em></td>
<td>30</td>
<td>2</td>
</tr>
<tr>
<td>Common silver barb <em>Puntius gonionotus</em></td>
<td>162</td>
<td>5</td>
</tr>
<tr>
<td>Small scale mud carp <em>Cirrhina microlepis</em></td>
<td>420</td>
<td>2</td>
</tr>
<tr>
<td>???</td>
<td>159</td>
<td>13</td>
</tr>
</tbody>
</table>
Food Stuff Sampling

- Two rounds of sampling done (one dry season, one wet season)
- 3 sites on wetland
- Analyses of morning glory, herbs, corn, tomato, fish, snails, sediment and water
- Cu, Cr, Zn done by AAS
Food Stuff Sampling

- Metals levels are higher in fish and snails than vegetables.

- Based on a survey more than 200 families, consumption of morning glory was highest.

- Risk assessment predicted that Zn, Cu and Cr originating from consumption of morning glory grown in the treatment wetland still does not pose any serious health risk to the community.
A potential health risk was identified for children consuming snails, specifically with respect to Cr.
Conclusions

- The wetlands are providing treatment!!!

- There are some potential health risks to the peri-urban community living on the wetland, based on biological indicators and for snail consumption for children

- This is the first data set of its kind collected in Cambodia
Challenges of Development

Infilling of wetlands – reduces capacity to treat waste, yet the growing population increases demand for treatment

Could Boeng Cheung Ek treatment be optimized? Yes, but there are other considerations – flood control, peri-urban community, ecosystem functions

Phnom Penh Post, January 16, 2009
Importance of Capacity Building