Solar Radiation - Driver of Innovations in Pond Design and Process Technologies

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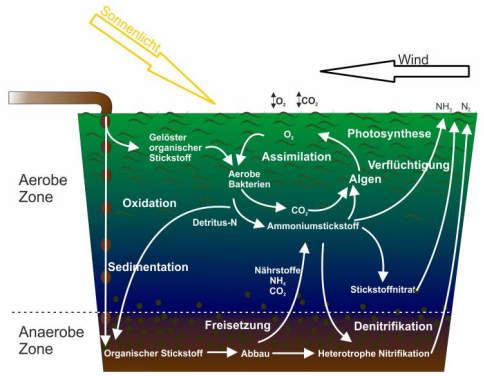

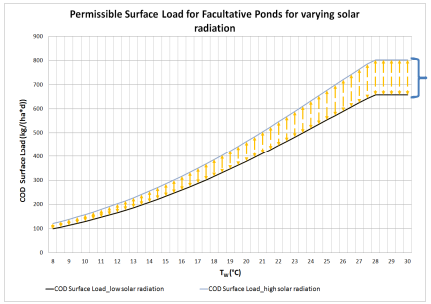

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- Methodology and preliminary Results
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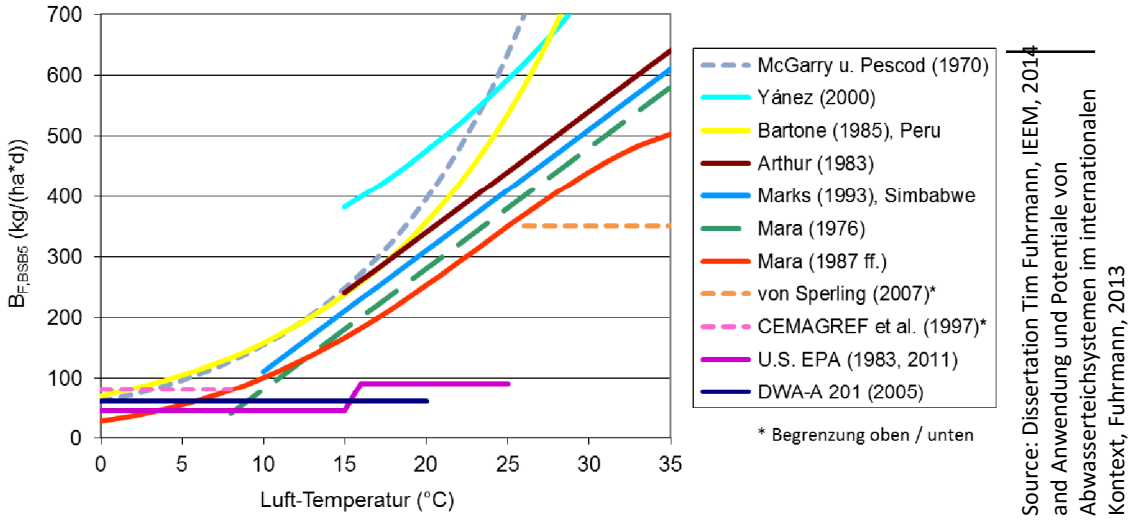
- Conclusion & Acknowledgement

Introduction & Background (1)

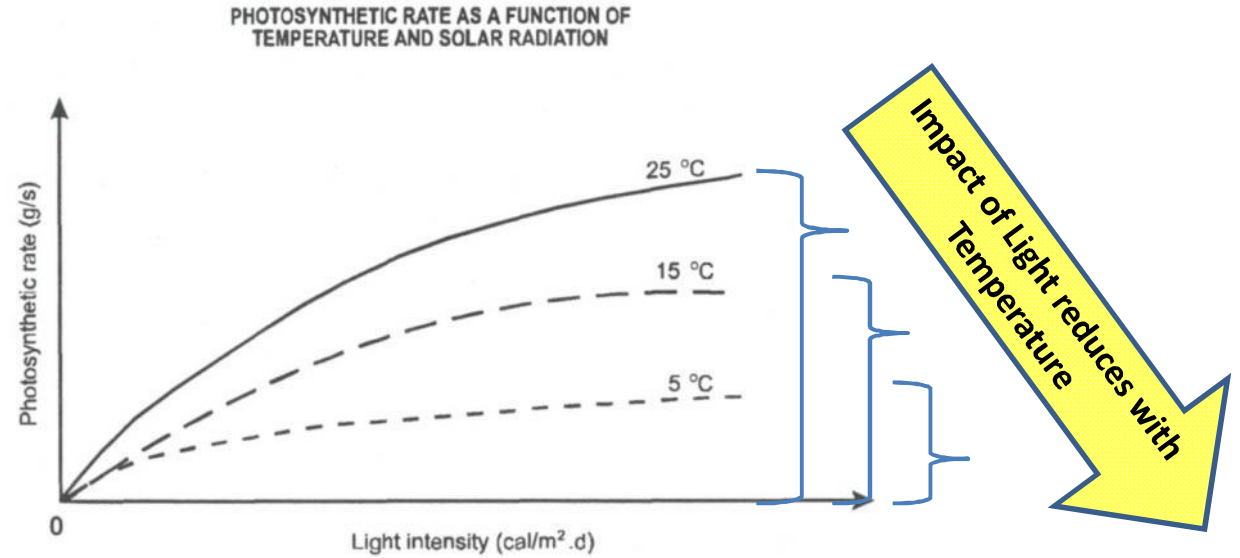
Author	Approach
DWA - A 201	*No Consideration of temperature*
Mc Garry und Pescod (1970)	$L_{F,BOD_5} = 60 \cdot 1{,}099^{T_A}$
Mara (1976)	$L_{F,BOD_5} = 20 \cdot T_A - 120$
Mara (1987 ff.)	$L_{F,BOD_5} = 350 \cdot (1{,}107 - 0{,}002 \cdot T_A)^{(T_A - 25)}$
Arthur (1983)	$L_{F,BOD_5} = 20 \cdot T_A - 60$
Yanez	



Source: Dissertation Tim Fuhrmann, IEEM, 2014 and Anwendung und Potentiale von Abwasserteichsystemen im internationalen Kontext, Fuhrmann, 2013

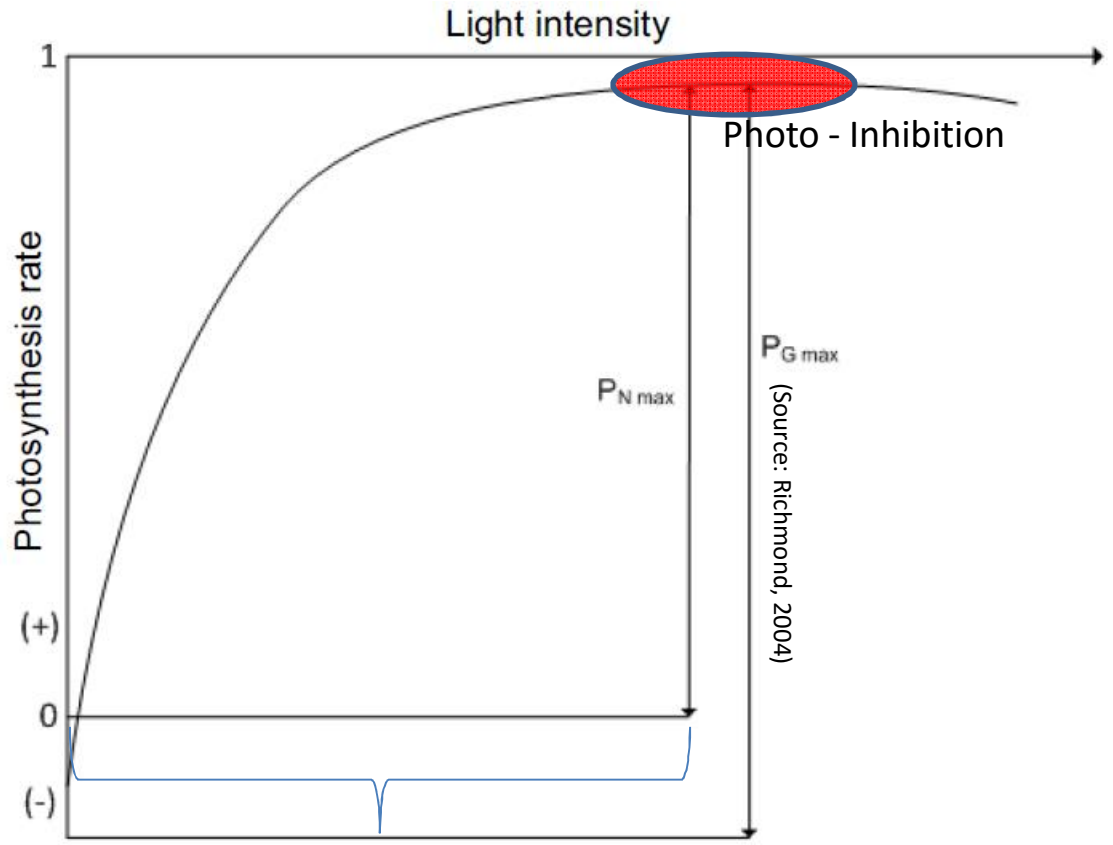
Introduction & Background (2)

Å Main (environmental) drivers in facultative ponds are: **Solar Radiation**, Temperature and Wind



(Source: von Sperling, 2007)

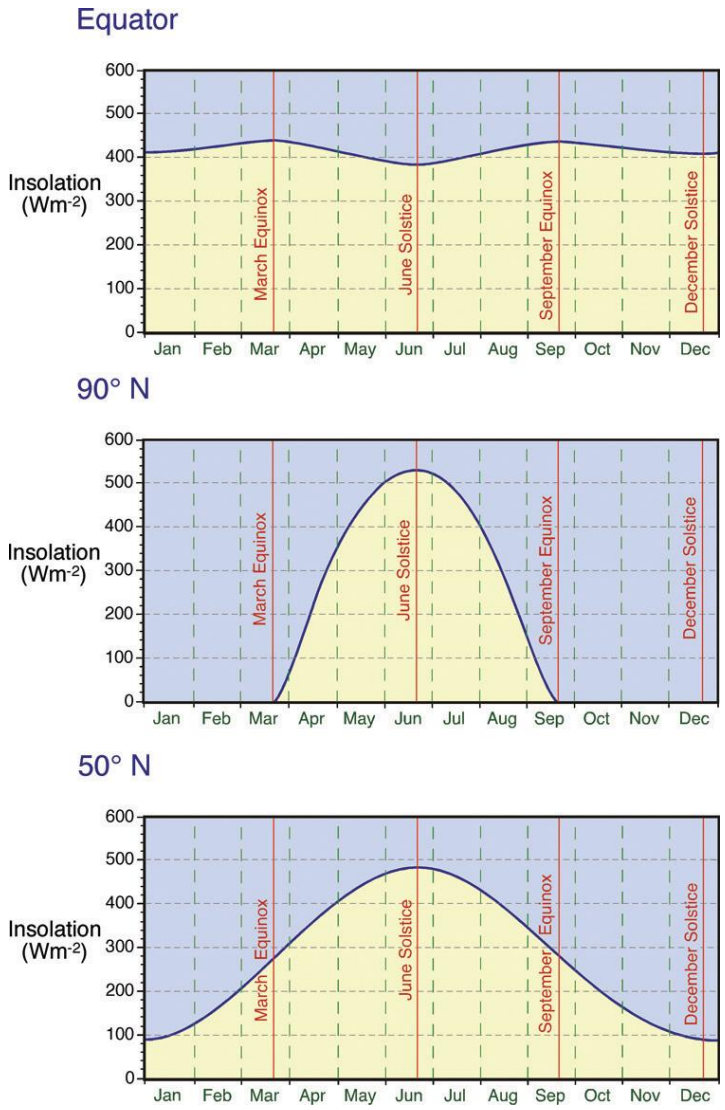
Introduction & Background (3)



EPA (2011): 54 to 540 W/m²

Introduction & Background (4)

Å Increase of Photosyntesis rate ranging between 54 and 540 W/m² before Photo - Inhibition takes place



Introduction & Background (5)

Existing sunlight based approaches

Å Oakley, 2005

$$L_{A,BOD} = (1{,}937^{-6}) \cdot RS_{\min} \left[\frac{kgBOD}{ha \cdot d} \right]$$

$L_{A,BOD}$ = BOD areal Loading rate (kg/ha d)

RS_{min} = Average minimal monthly Insolation (kWh/m² d)

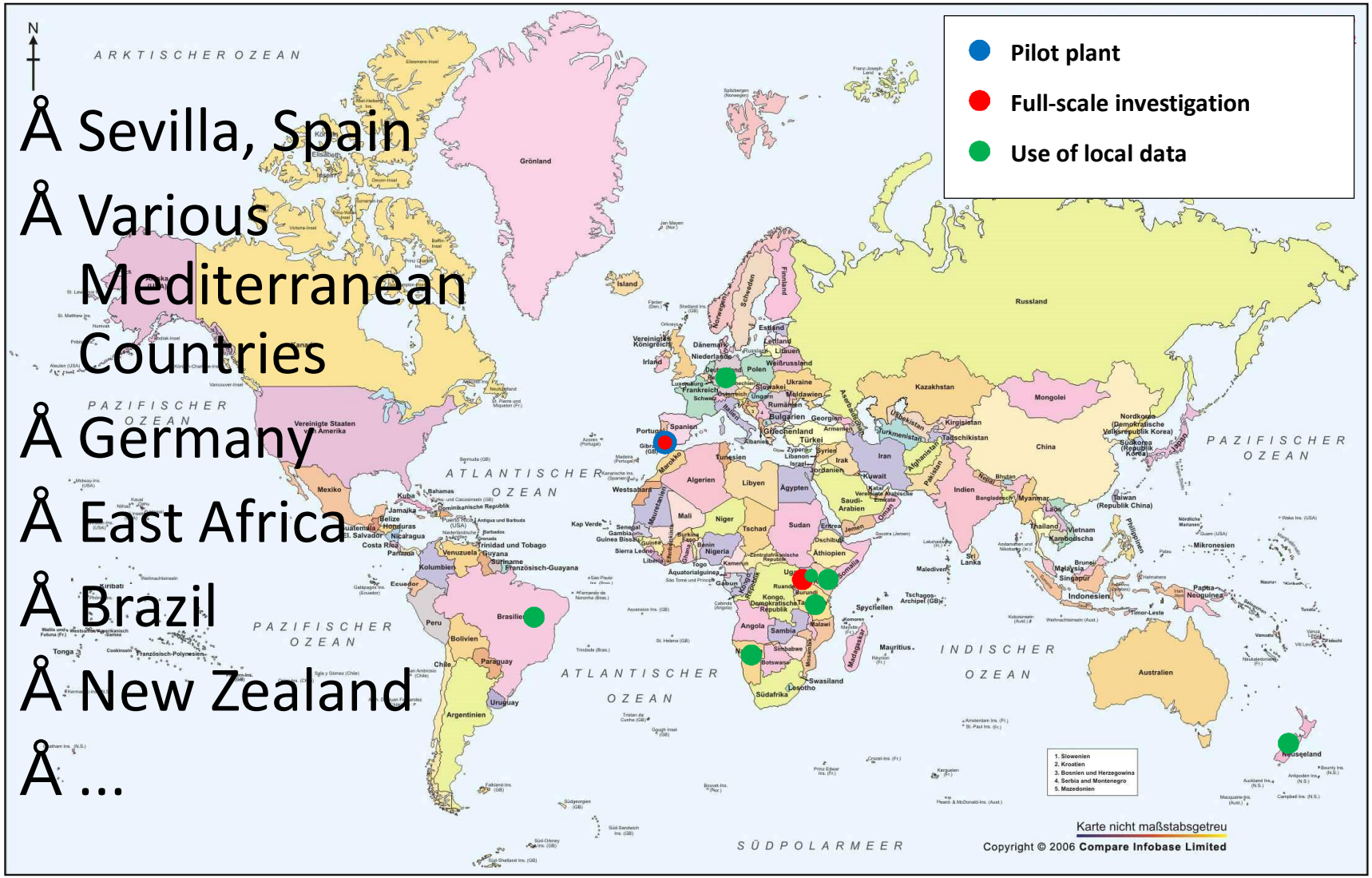
Å Gloyna Methode

$$V = 0{,}035Q(BOD)(1{,}099)^{Light(35-T)/250}$$

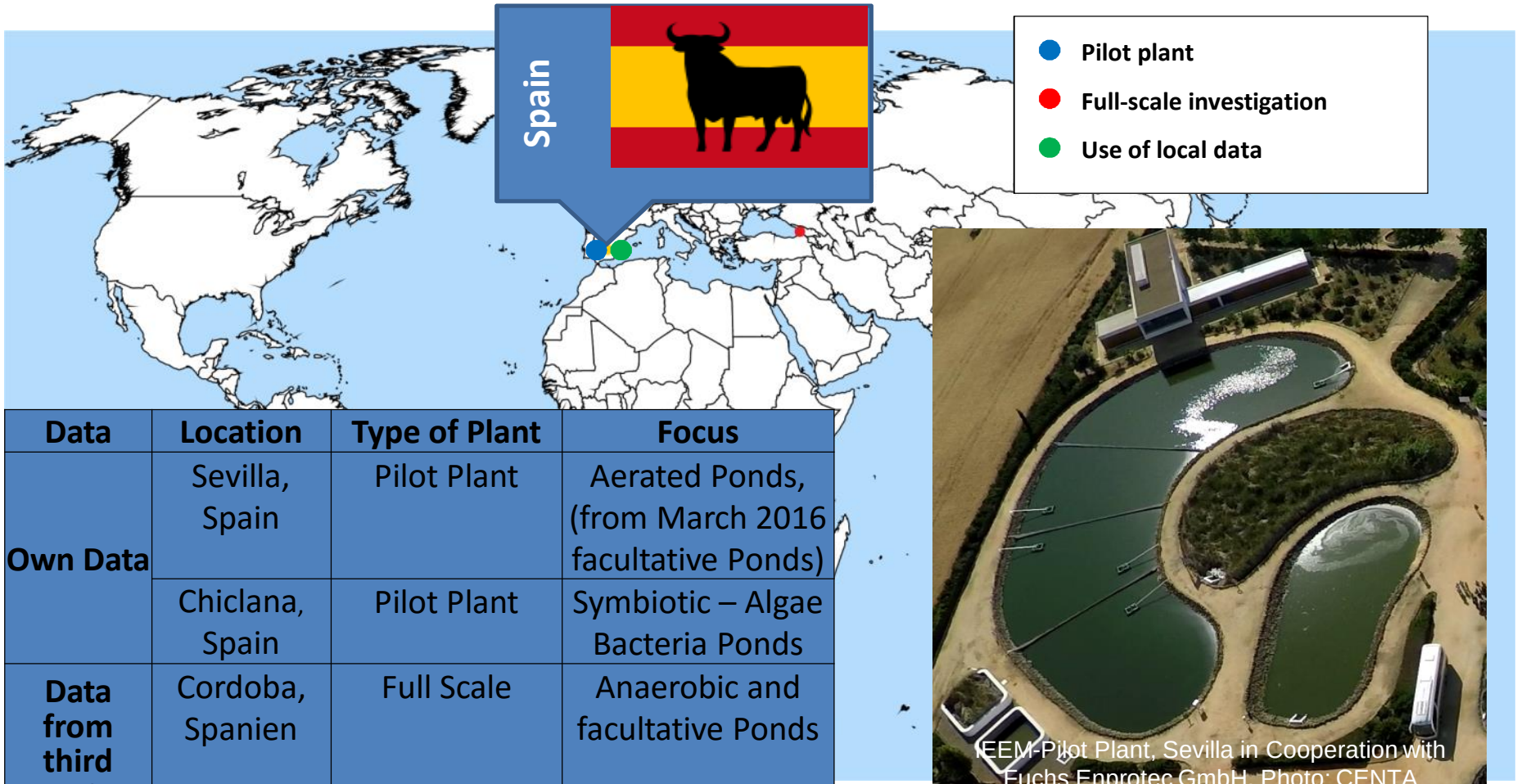
BOD = BOD_5 in the system influent (mg/L).
$LIGHT$ = Solar radiation (langleys).
V = Pond volume (m^3).
Q = Influent flow rate (m^3/day).
T = Pond temperature (°C).

Data Acquisition (1)

- Sevilla, Spain
- Various Mediterranean Countries
- Germany
- East Africa
- Brazil
- New Zealand
- …



Data Acquisition (2)

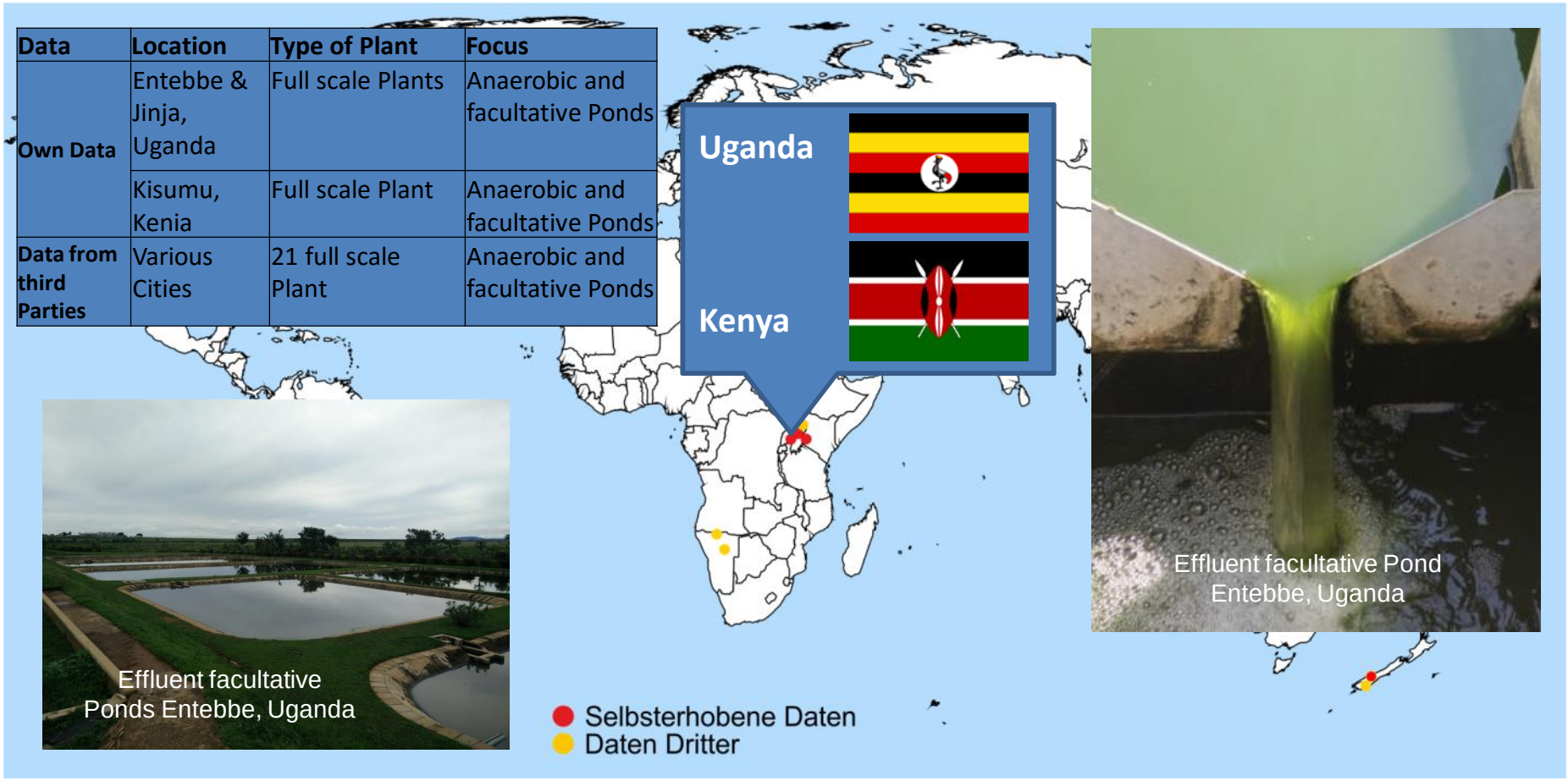


Data	Location	Type of Plant	Focus
Own Data	Sevilla, Spain	Pilot Plant	Aerated Ponds, (from March 2016 facultative Ponds)
	Chiclana, Spain	Pilot Plant	Symbiotic – Algae Bacteria Ponds
Data from third Parties	Cordoba, Spanien	Full Scale	Anaerobic and facultative Ponds

IEEM-Pilot Plant, Sevilla in Cooperation with Fuchs Enprotec GmbH, Photo: CENTA

Data Acquisition (3)

Data	Location	Type of Plant	Focus
Own Data	Entebbe & Jinja, Uganda	Full scale Plants	Anaerobic and facultative Ponds
	Kisumu, Kenia	Full scale Plant	Anaerobic and facultative Ponds
Data from third Parties	Various Cities	21 full scale Plant	Anaerobic and facultative Ponds



Data Acquisition (4)

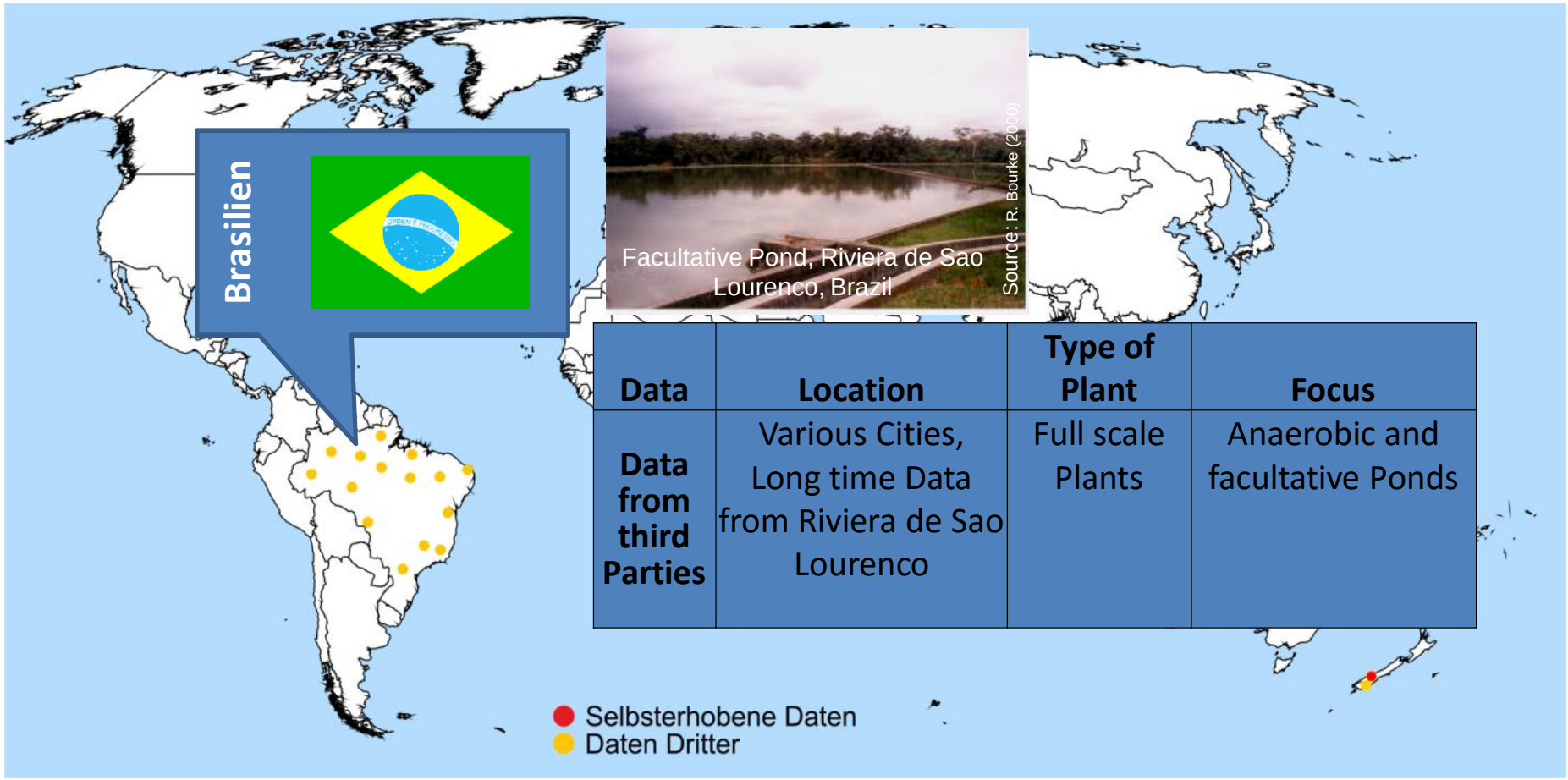
Data	Location	Type of Plant	Focus
Data from third Parties	Invercargill, Queenstown, Neuseland	Full scale Plants	Anaerobic and facultative Ponds **(Cold Climate)**

New Zealand

NZ

Selbsterhobene Daten
Daten Dritter

Data Acquisition (5)



Data	Location	Type of Plant	Focus
Data from third Parties	Various Cities, Long time Data from Riviera de Sao Lourenco	Full scale Plants	Anaerobic and facultative Ponds

Methodology and preliminary Results

Design Formula facultative pond (empiric approach Mara 1987)

$$L_{A,COD} = 615 \cdot (1{,}125 - 0{,}0023 \cdot T_W)^{(Tw-25)} \cdot FS$$

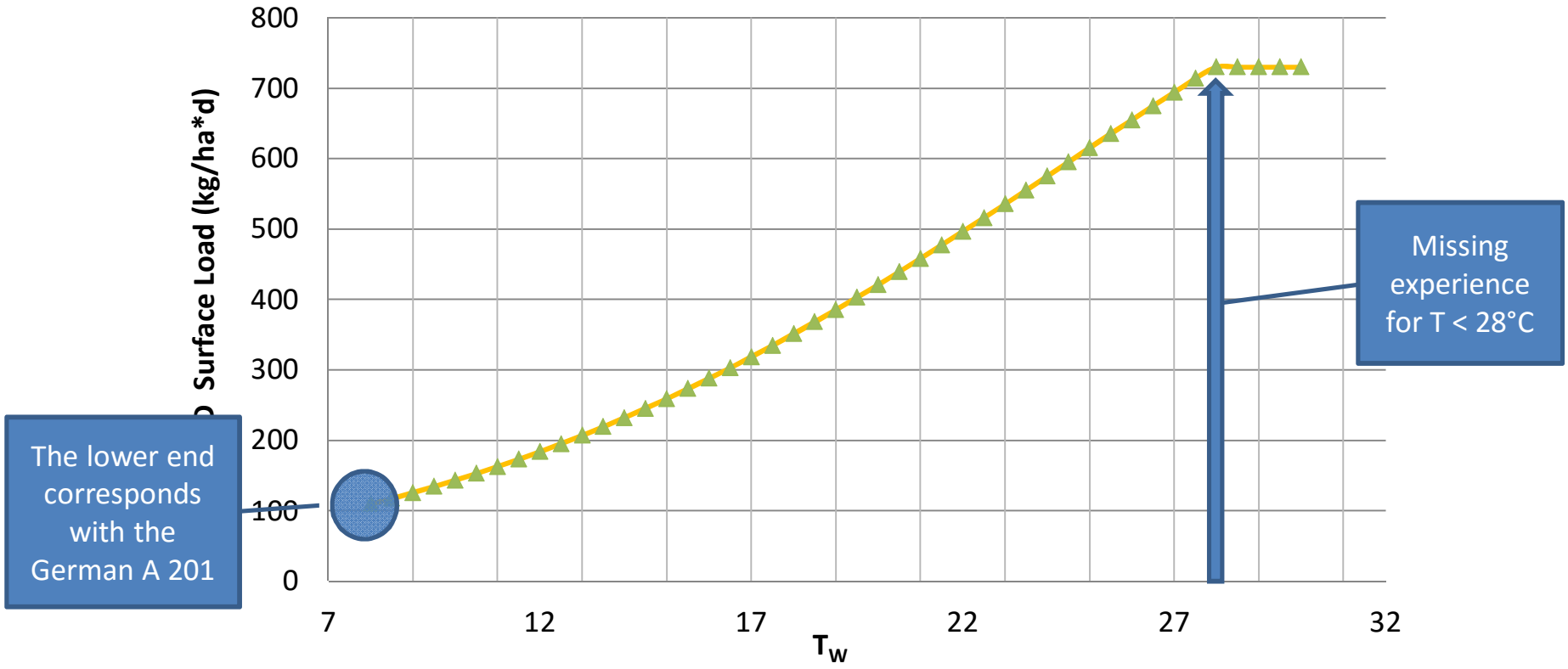
NEW!

- 615 COD reference surface loading kg/ha/d at 25°C.
- Empiric Factor to adjust removal rate for varying temperatures
- Reference temperature for BOD-removal rate
- NEW: Factor to consider influence of solar radiation

Methodology and preliminary Results

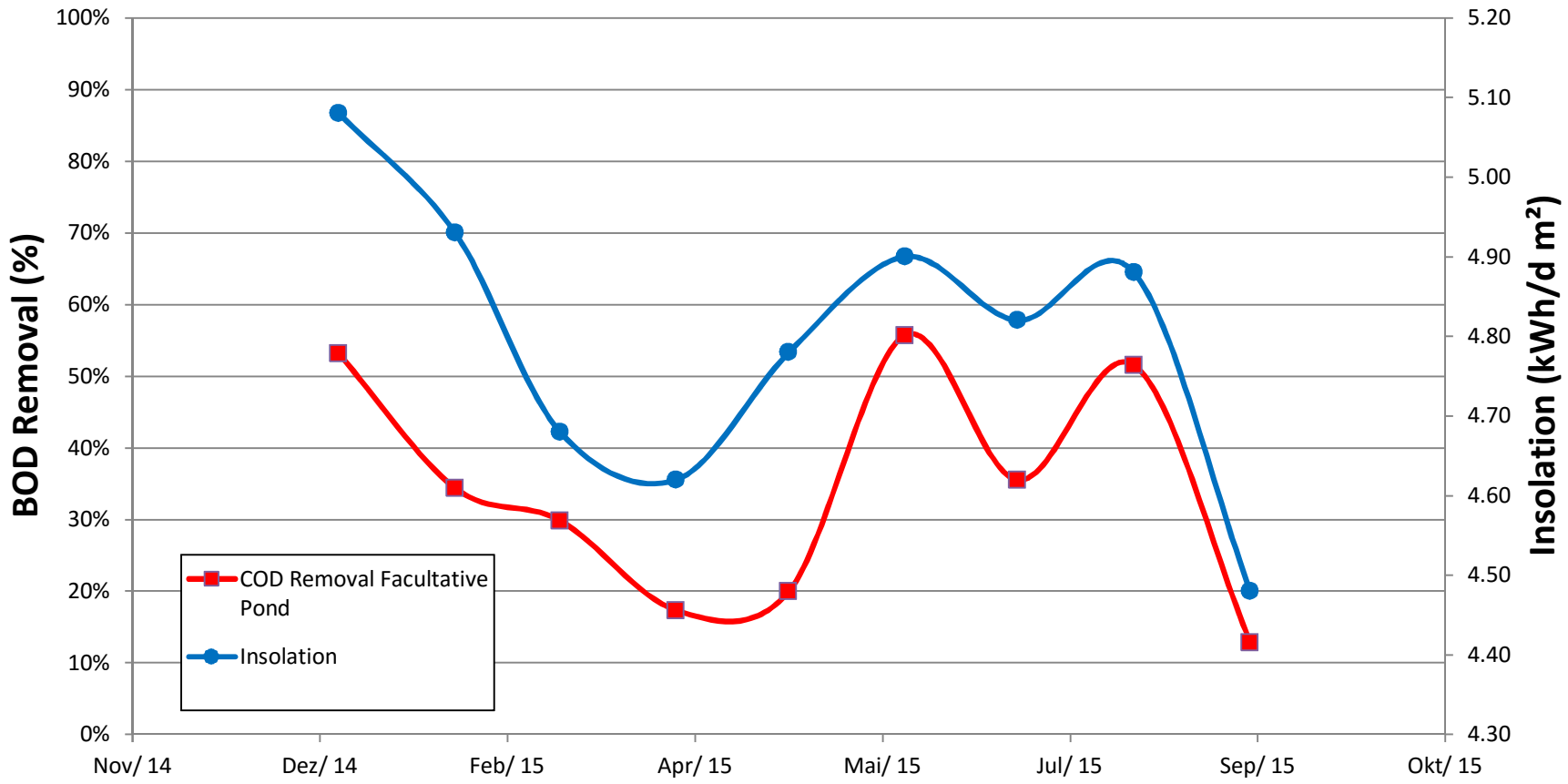
Design Formula facultative pond (empiric approach Mara 1987)

$$L_{A,CSB} = 615 \cdot (1{,}125 - 0{,}0023 \cdot T_W)^{(Tw-25)}$$

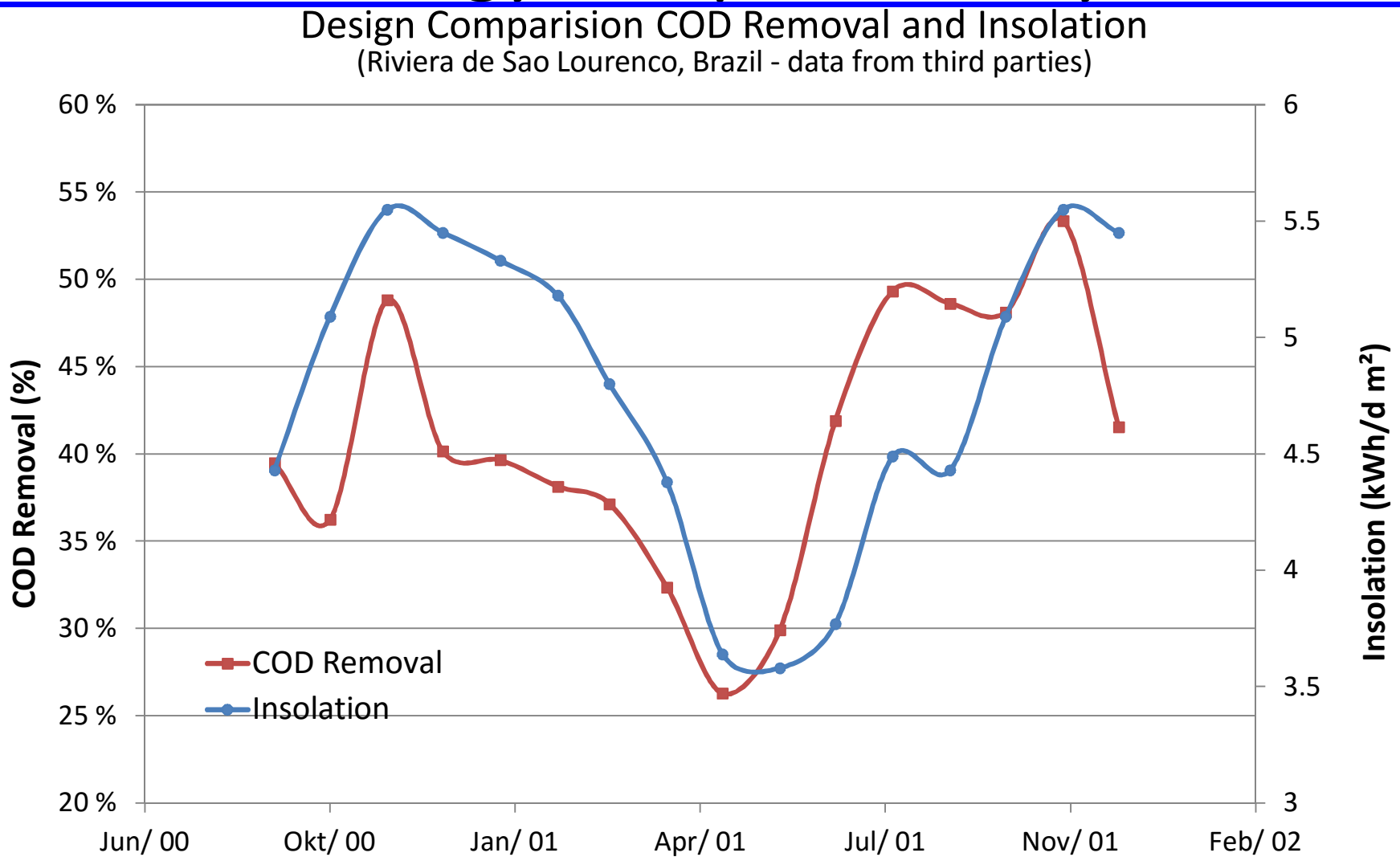


Methodology and preliminary Results

Design Comparision COD Removal and Insolation (Entebbe, Uganda – own data)



Methodology and preliminary Results



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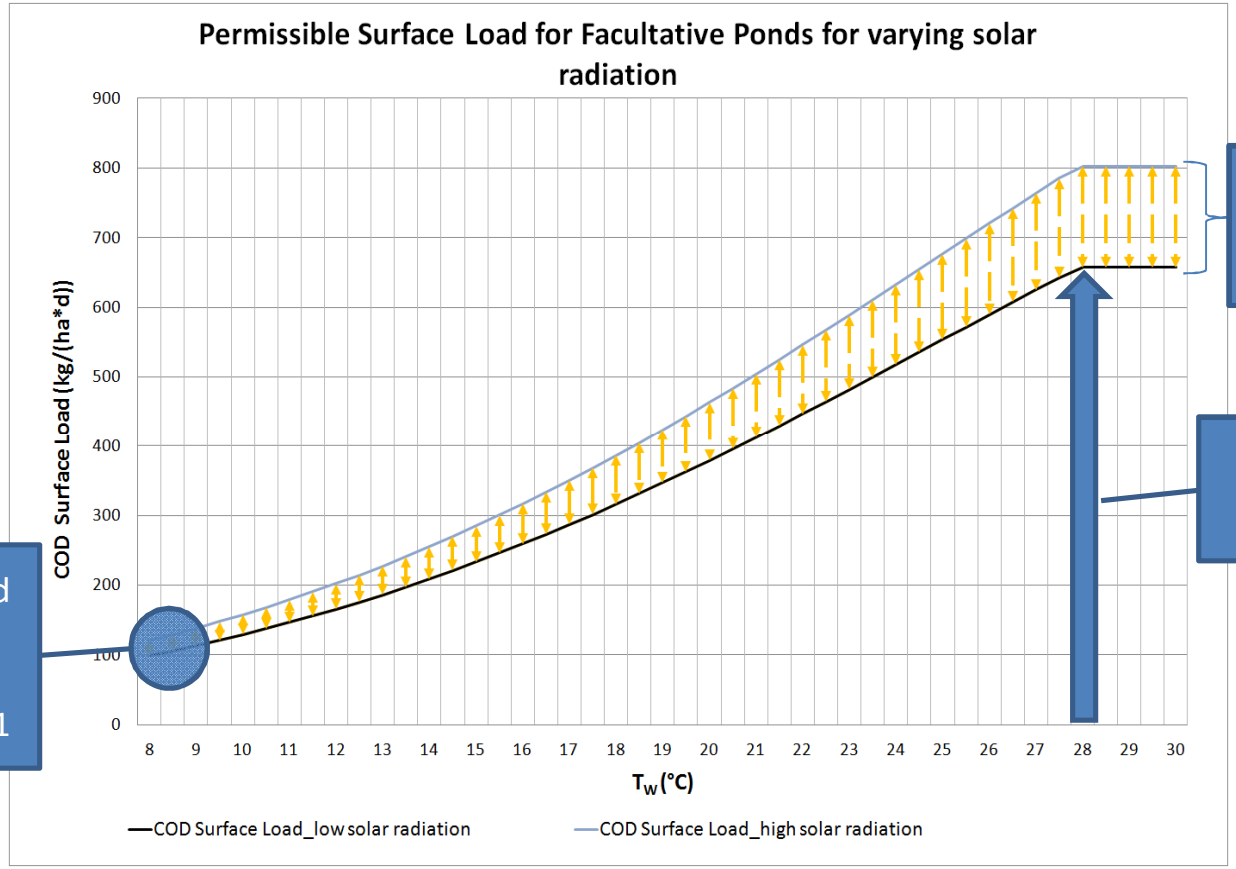


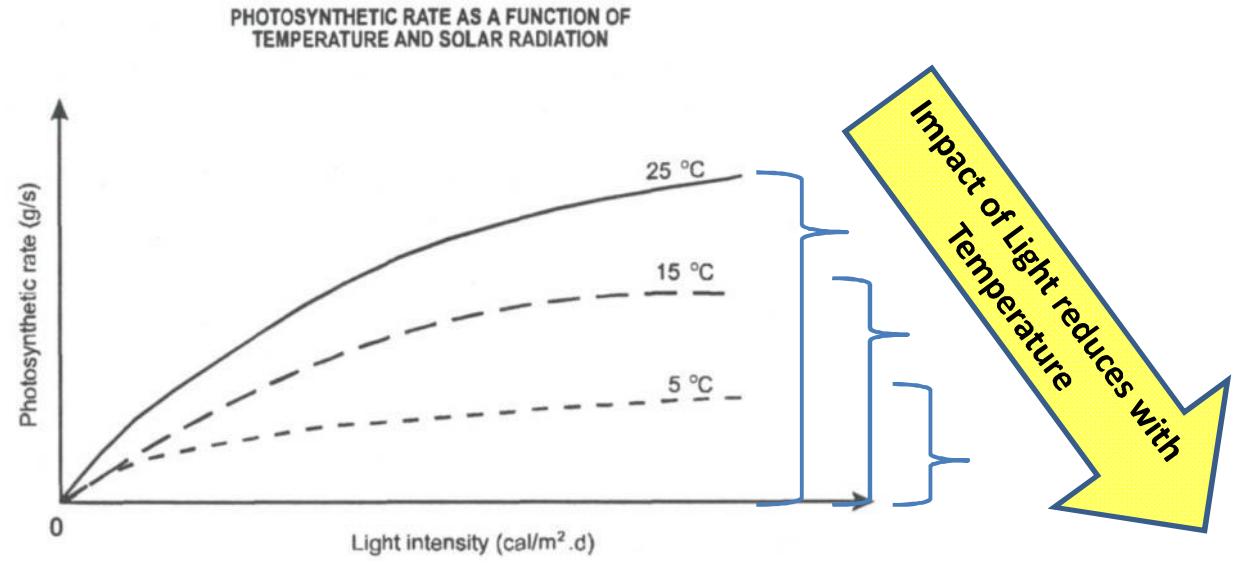
Quantitive range still under validation

Missing expierience for T < 28°C

The lower end corresponds with the German A 201

Introduction & Background (1)

Å REMINDER:

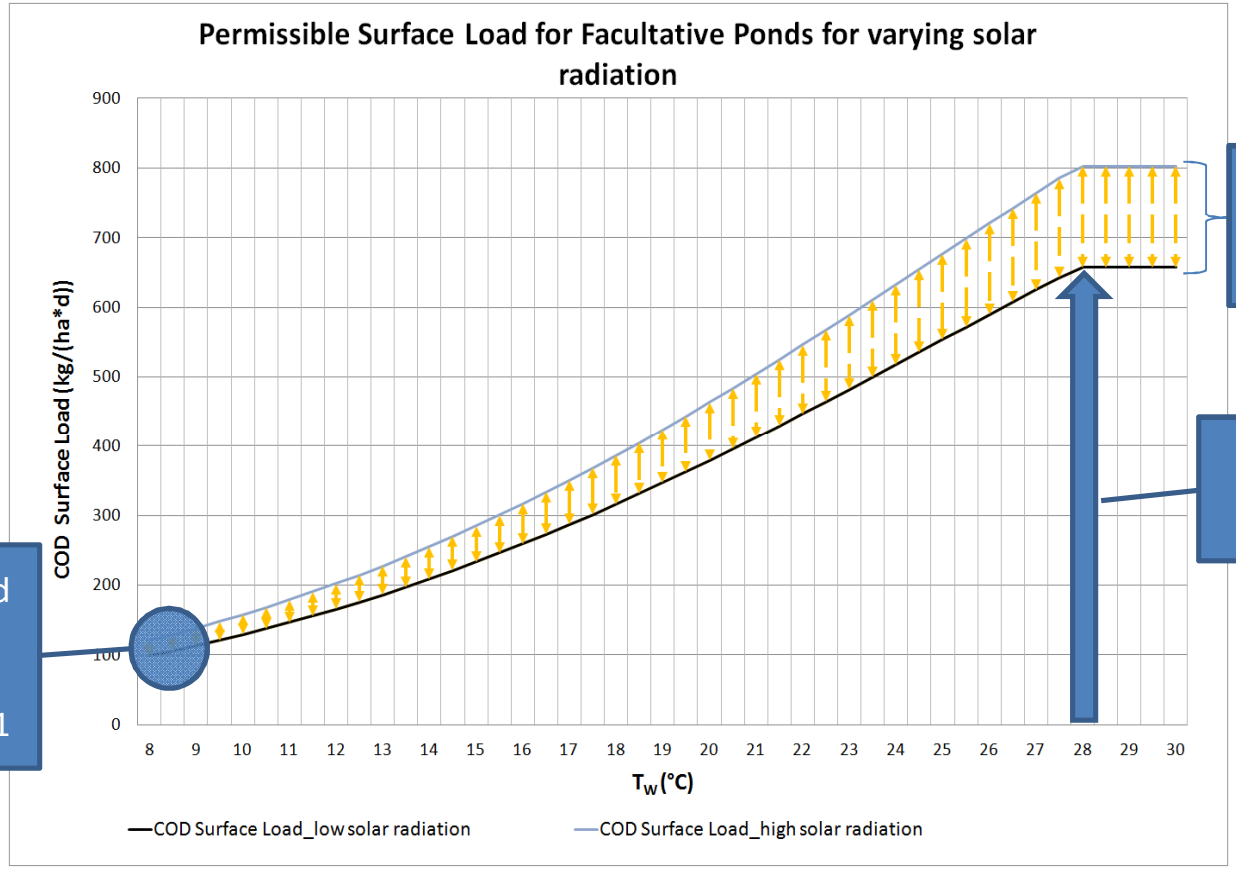


(Source: von Sperling, 2007)

Methodology and preliminary Results

Design Formula facultative pond (empiric approach Mara 1987)

$$L_{A,COD} = 615 \cdot (1{,}125 - 0{,}0023 \cdot T_W)^{(Tw-25)} \cdot FS$$



Quantitive range still under validation

Missing expierience for T < 28°C

The lower end corresponds with the German A 201

Methodology and preliminary Results

Aerated Ponds (empiric approach by FUCHS Enprotech GmbH)

$$L_{V,\,COD} = 33{,}6 \cdot e^{0{,}0347 \cdot TW} \cdot k_1 \cdot k_2$$

Factor	Value
k_1 for number of aerated ponds (in series)	0.75 for one aerated unit 1.0 for two aerated units 1.2 for three aerated units
k_2 for slope material	0.8 for membrane (foil) 1.0 for natural layer 1.2 for rough surface such as geomembrane or gravel

- The formula is a further development of the German ATV - A 201 with aditional (empircal) parameters for Temperature (which was neglected in the current A 201)
- The FUCHS brothers have developed this (empirical) formula with data from Germany as well as from Mediterranean countries and practical experiences collected from other regions worldwide.
- A temperature coefficient is introduced, which allows improved pond design adapted to a greater range of climatic conditions (different from the current A 201).
- Additional design parameters are introduced with respect to the number of aerated ponds in series and the surface structure of the pond liner.

Conclusion & Acknowledgement

- **Successful Validation** of design approach for faculative (with COD and Water Temperature). Continuation is needed with more data from various sites.
- **Still in Process**: Including one additional parameter for Insulation. First results are promising.
- **Aerated Ponds**: Successful implementation of additional design parameters: number of aerated ponds in series and the surface structure of the pond liner.
- **Acknowledgement**: The project is financially supported by the German Federal Ministry of Education and Research (www.bmbf.de; www.expoval.de/en) and co-financed by the industrial project partner Fuchs Enprotec

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Conclusion & Acknowledgement