Waste Stabilization Ponds: Past, Present and Future

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UNIVERSITY OF LEEDS

Natural *vs* Conventional Wastewater Treatment

❖ Basically a choice between LAND and ELECTRICITY:

- Money spent on land is an **investment**
- Money spent on electricity is **money gone for ever**

$$$$$

WSP: The Past

- Early work in USA (Caldwell, 1946; 'Ten States' Standards)
- Pioneering research by Oswald (USA) and Marais (southern Africa)

◄ Bill Oswald

Gerrit Marais ►

Bill Oswald & WSP

THE
SCIENTIFIC MONTHLY
JANUARY 1952

Symposium on the Role of Ecology in Water Pollution Control

The papers presented here are based on addresses given in the symposium sponsored by the Ecological Society of America at the Western Division meetings of the AAAS in Los Angeles last June. Concerning the authors, Dr. Ludwig and Mr. Paul are sanitary engineers, Dr. Mohr is a protozoologist, Dr. Newcombe and Dr. Phinney are botanists, and Mr. Oswald is a research engineer.

▶ Role of Algae in Sewage Oxidation Ponds

HARVEY F. LUDWIG and WILLIAM J. OSWALD
Sanitary Engineering Laboratories, University of California, Berkeley

Photosynthetic Reclamation of Organic Wastes

HAROLD B. GOTAAS, WILLIAM J. OSWALD,
HARVEY F. LUDWIG

Dr. Gotaas is professor of sanitary engineering and director of the Sanitary Engineering Research Laboratory of the University of California at Berkeley. He received his training at the University of South Dakota, Iowa State College, and Harvard University. During World War II, he served in a military capacity in Latin America with the Institute of Inter-American Affairs as chief engineer, director of health and sanitation, executive vice president, and finally president

Scientific Monthly, 1954

High-rate algal ponds: low-cost protein for animal feeds – “sewage to beefsteak”

Algal–bacterial mutualism

Role of Algae in Sewage Oxidation Ponds

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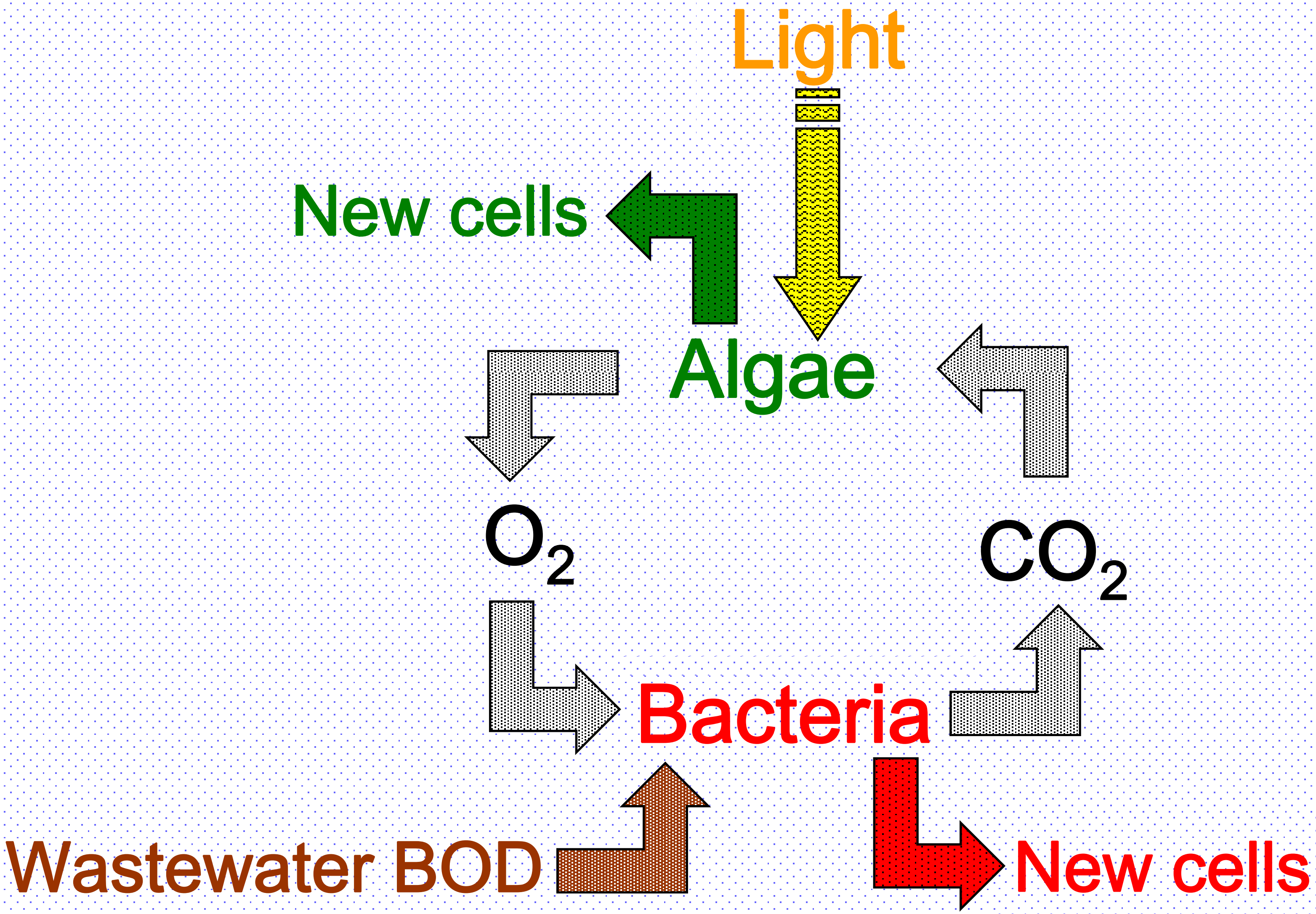


Gerrit Marais & WSP

1961:

'A rational theory for the design of sewage stabilization ponds in central and south Africa'
***Transactions of the South African Institution of Civil Engineers* 3, 205–227**

Application of first-order kinetics in a completely mixed reactor to the design of facultative ponds:

$$L_e = \frac{L_i}{1 + k_1\theta}$$

Gerrit Marais & WSP

1961:

'A rational theory for the design of sewage stabilization ponds in central and south Africa'
***Transactions of the South African Institution of Civil Engineers* 3, 205–227**

1966:

Bull. Org. mond. Santé }
Bull. Wld Hlth Org. } 1966, **34**, 737-763

New Factors in the Design, Operation and Performance of Waste-stabilization Ponds

G. v. R. MARAIS [1]

In the developing countries, the unit costs of waste-stabilization ponds are generally low. Moreover, in the tropics and subtropics, the environmental conditions are conducive to a high level of pond performance. In view of this, the theory, operation and performance of such ponds under these conditions have been studied.

Gerrit Marais & WSP

1970

Dynamic behaviour of oxidation ponds

***Second International Symposium for Waste Treatment Lagoons*, University of Kansas**

"Anaerobic pretreatment is so advantageous that the first consideration in the design of a series of ponds should always include the possibility of anaerobic pretreatment."

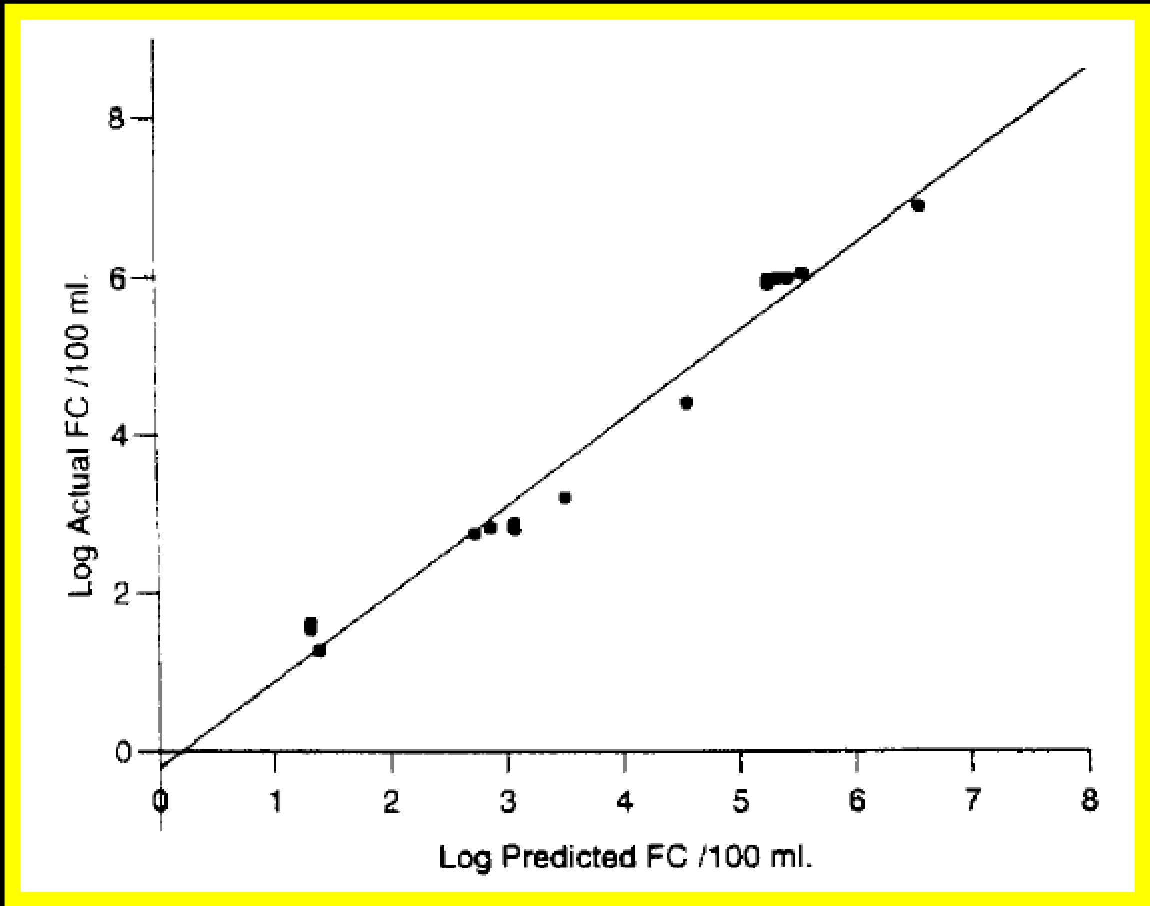
Gerrit Marais & WSP

1974:

Faecal bacterial kinetics in waste stabilization ponds
Journal of the Environmental Engineering Division,
ASCE, 100 (EE1), 119−139.

$$K_{B(T)} = 2.6(1.19)^{T-20}$$

and so for the first time it became possible to design WSP for faecal bacterial removal.



WST **31** (12), 129−139 (1995)

Excellent agreement between actual FC numbers in pond effluents in northeast Brazil and numbers predicted by Marais' equation (25°C)

The Present of WSP owes much to

◄ Bill Oswald

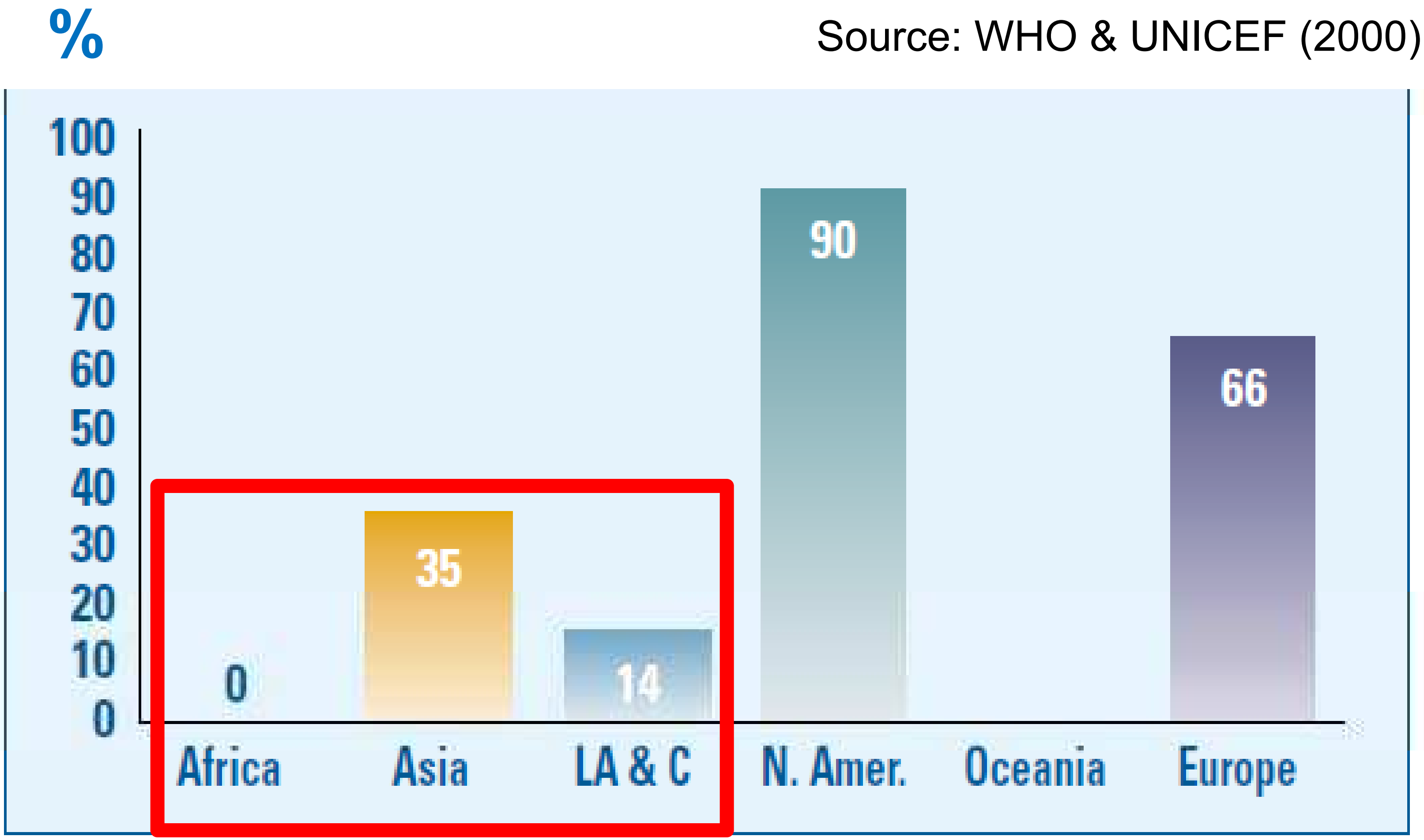
Gerrit Marais ►

Our Present:

A world with too little wastewater treatment

Effective wastewater treatment – 2000

Source: WHO & UNICEF (2000)



WSP: The Present

- ~2500 WSP systems in France
- ~3000 in Germany (inc. ~1500 in Bavaria)
- ~7500 in USA (⅓ of all WWTP are WSP)
- and in many other countries

WSP: The Present

- **Major WSP research programmes at, for example:**

University of California at Berkeley

Federal Universities of Paraíba and Minas Gerais, Brazil; Univalle, Colombia

Flinders University, Australia

AIT, Thailand; Massey University, NZ

Universities of Montpellier I & II, France

University of Leeds, UK

WSP: The Present

- IWA International WSP Conferences (Lisbon, 1987 – Belo Horizonte 2009)
- Several design guides, manuals and books
- But one major disappoint-ment:

BRITISH STANDARD

Actually a European standard

BS EN 12255-5:1999
Incorporating Corrigendum No. 1

Wastewater treatment plants —

Part 5: Lagooning processes

?

Table 1: Requirements for discharges from urban waste water treatment plants subject to Articles 4 and 5 of the Directive. The values for concentration or for the percentage of reduction shall apply.

Parameters	Concentration	Minimum percentage of reduction ([1])	Reference method of measurement
Biochemical oxygen demand (BOD5 at 20 °C) without nitrification ([2])	25 mg/l O_2	70-90 40 under Article 4 (2)	Homogenized, unfiltered, undecanted sample. Determination of dissolved oxygen before and after five-day incubation at 20 °C ± 1 °C, in complete darkness. Addition of a nitrification inhibitor
Chemical oxygen demand (COD)	125 mg/l O_2	75	Homogenized, unfiltered, undecanted sample Potassium dichromate
Total suspended solids	35 mg/l ([3]) 35 under Article 4 (2) (more than 10 000 p.e.) 60 under Article 4 (2) (2 000-10 000 p.e.)	90 ([3]) 90 under Article 4 (2) (more than 10 000 p.e.) 70 under Article 4 (2) (2 000-10 000 p.e.)	— Filtering of a representative sample through a 0,45 µm filter membrane. Drying at 105 °C and weighing — Centrifuging of a representative sample (for at least five mins with mean acceleration of 2 800 to 3 200 g), drying at 105 °C and weighing

([1]) Reduction in relation to the load of the influent.
([2]) The parameter can be replaced by another parameter: total organic carbon (TOC) or total oxygen demand (TOD) if a relationship can be established between BOD5 and the substitute parameter.
([3]) This requirement is optional.

Analyses concerning discharges from lagooning shall be carried out on filtered samples; however, the concentration of total suspended solids in unfiltered water samples shall not exceed 150 mg/l.

Urban Waste Water Treatment Directive (1991)

So for WSP effluents:

≤25 mg <u>filtered</u> BOD/l & ≤150 mg SS/l

WSP: The Present

Improved understanding of:

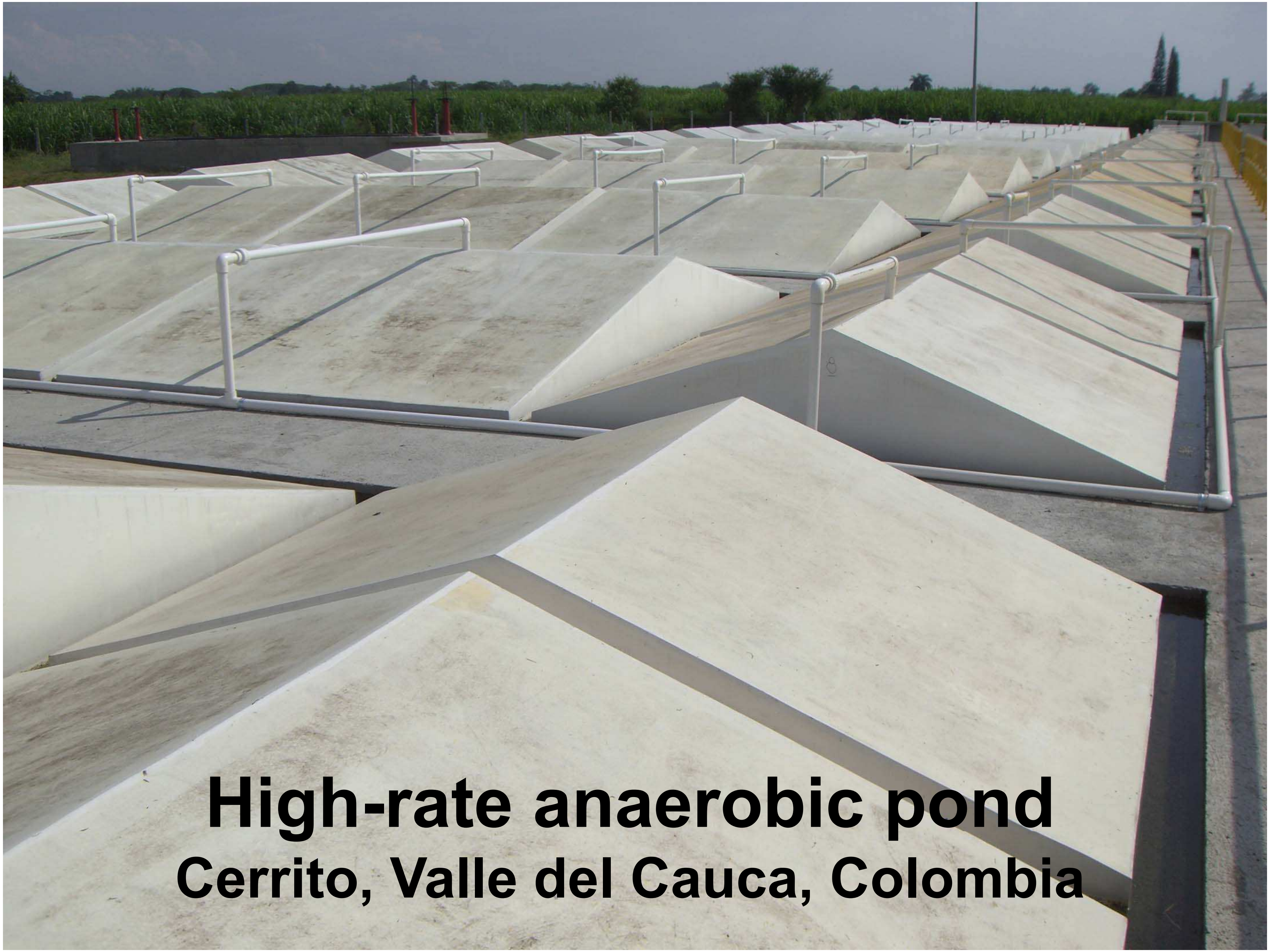
- **Faecal bacterial removal mechanisms (including removal of *Vibrio cholerae*)**
- **Nitrogen removal mechanisms and pathways**
- **Facultative pond performance in temperate climates**

Ability to design WSP specifically for helminth egg removal

WSP: The Present

Several important developments:

- **Greatly improved understanding of WSP hydraulics, enabling rational design of baffles (dramatic improvement in performance – so much so that now wrong not to baffle facultative ponds)**
- **High-rate anaerobic ponds**
- **Rock filters to treat <u>fac</u>. pond effluents**



High-rate anaerobic pond

Cerrito, Valle del Cauca, Colombia

WSP effluents: algal SS

We shouldn't think of algal SS as a problem!

Conventional wastewater treatment:

Biological treatment + secondary sedimentation

Waste stabilization ponds:

Facultative pond + rock filter

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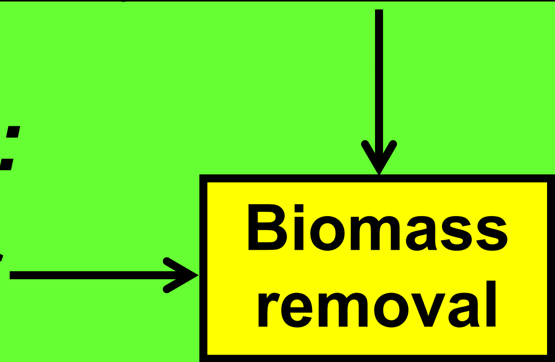

WSP effluents: algal SS

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Conventional wastewater treatment:

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Waste stabilization ponds:

Facultative pond + rock filter

↓

"WSP system"

ROCK FILTERS

- Used in the US for over 30 years to 'polish' maturation pond effluents, but actually better to use them to polish <u>facultative</u> pond effluents

- Purpose: to remove algal SS and associated BOD


Planted filter (*Typha*)
Unaerated filter
Aerated filter

All receiving <u>facultative</u> pond effluent

Summer

Results for effluent ammonia-N/l:

Aerated RF: <3 mg/l

Unaerated RF: ~7 mg/l

Planted bed: ~4 mg/l

BUT

<u>Winter</u>

Results for effluent ammonia-N/l:

Aerated RF: <3 mg/l

Unaerated RF: ~8 mg/l

Planted bed: ~7 mg/l

Aerated rock filter

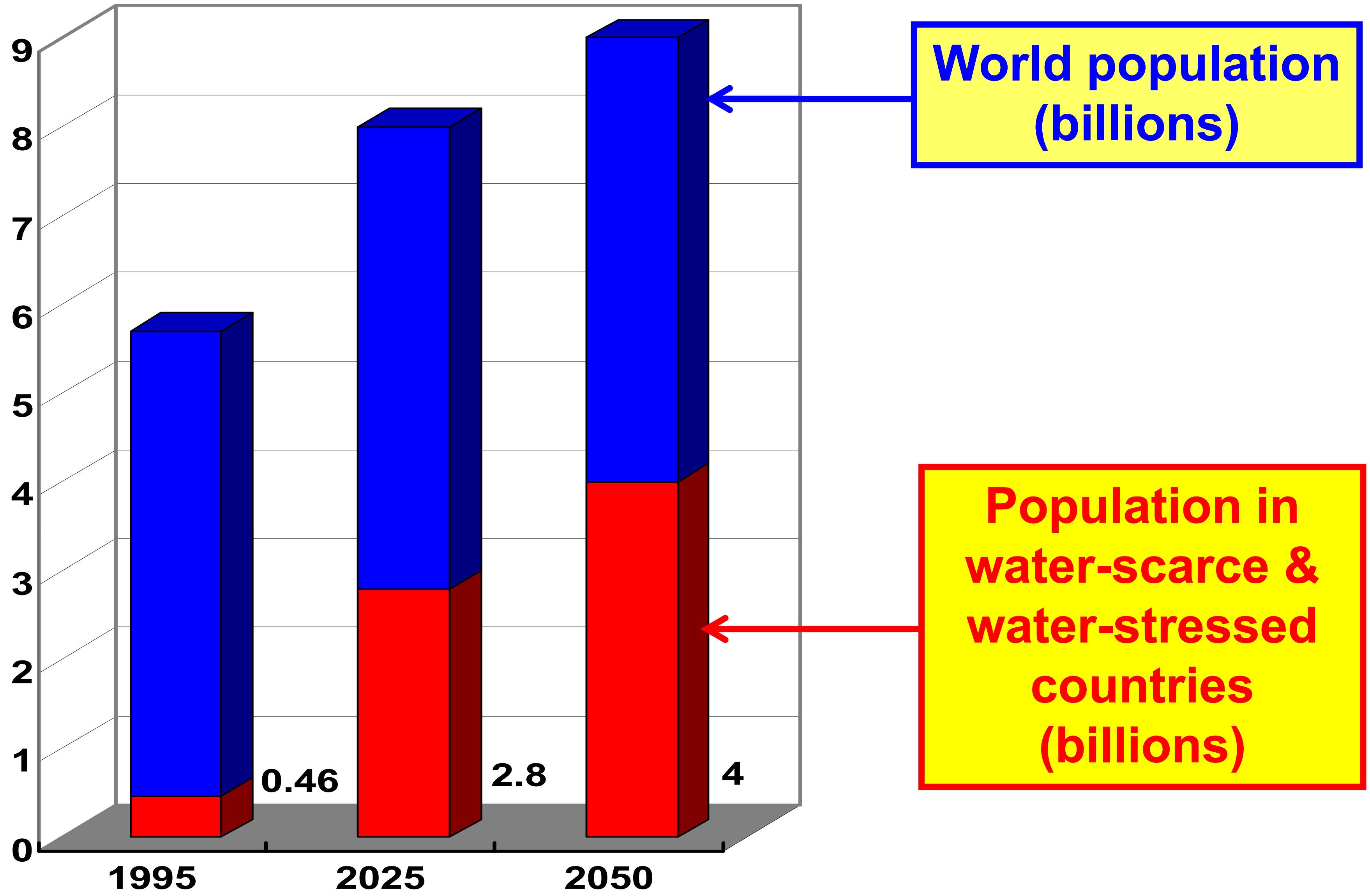
Mean effluent quality 2006

HLR = 0.6 day^{-1}

BOD	9 mg/l
SS	7 mg/l
Amm.N	2.6 mg/l
F. coliforms	<1000/100 ml

Our Future:

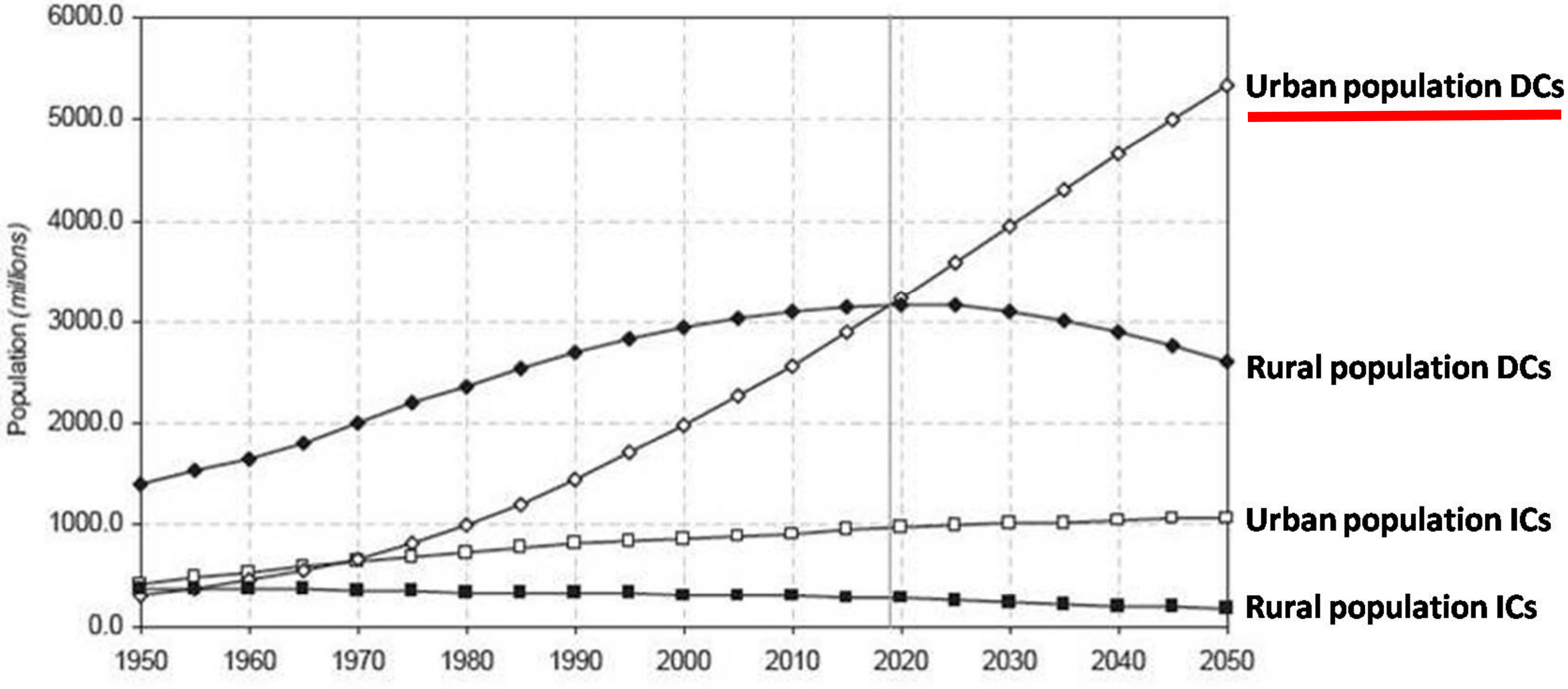
A water-short world


World population (billions)
Population in water-scarce & water-stressed countries (billions)
9
8
7
6
5
4
3
2
1
0
0.46
2.8
4
1995
2025
2050

Our Future:

An urban world

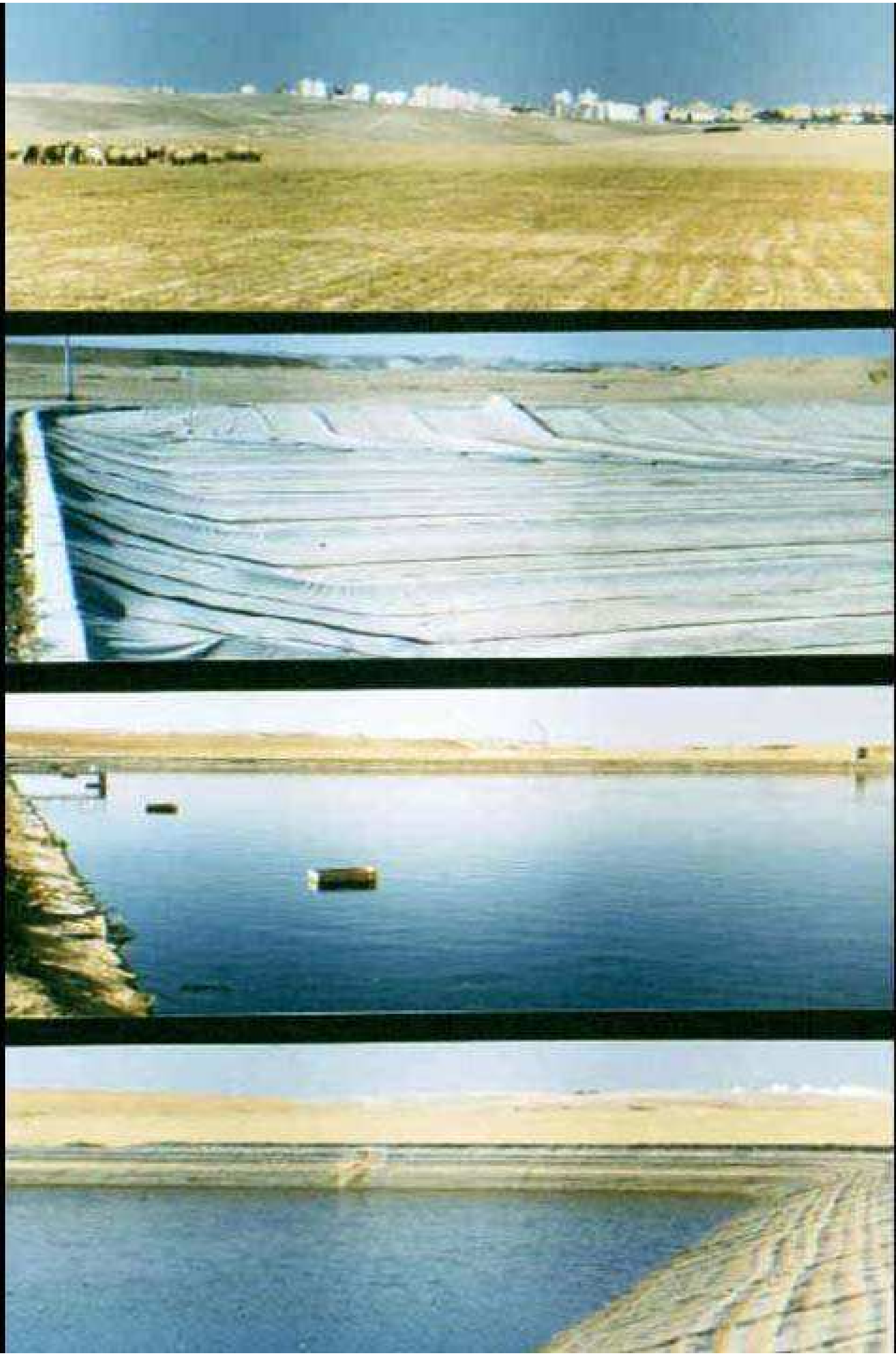
Actually a poor urban world



Source: *World Urbanization Prospects: The 2007 Revision*

WSP: The Future

- Treated wastewater use in aquaculture and/or agriculture (preferably "and")
- "Water for Cities, Treated Wastewater for Agriculture"
- WSP especially suitable for treatment prior to reuse
- Wastewater Storage & Treatment Reservoirs likely to be used much more



WSTR at Arad, Israel

Sequential batch-fed WSTR

Covered anaerobic pond

Biofuel production (CH_4)

WSTR in “rest” phase

WSTR in “use” phase

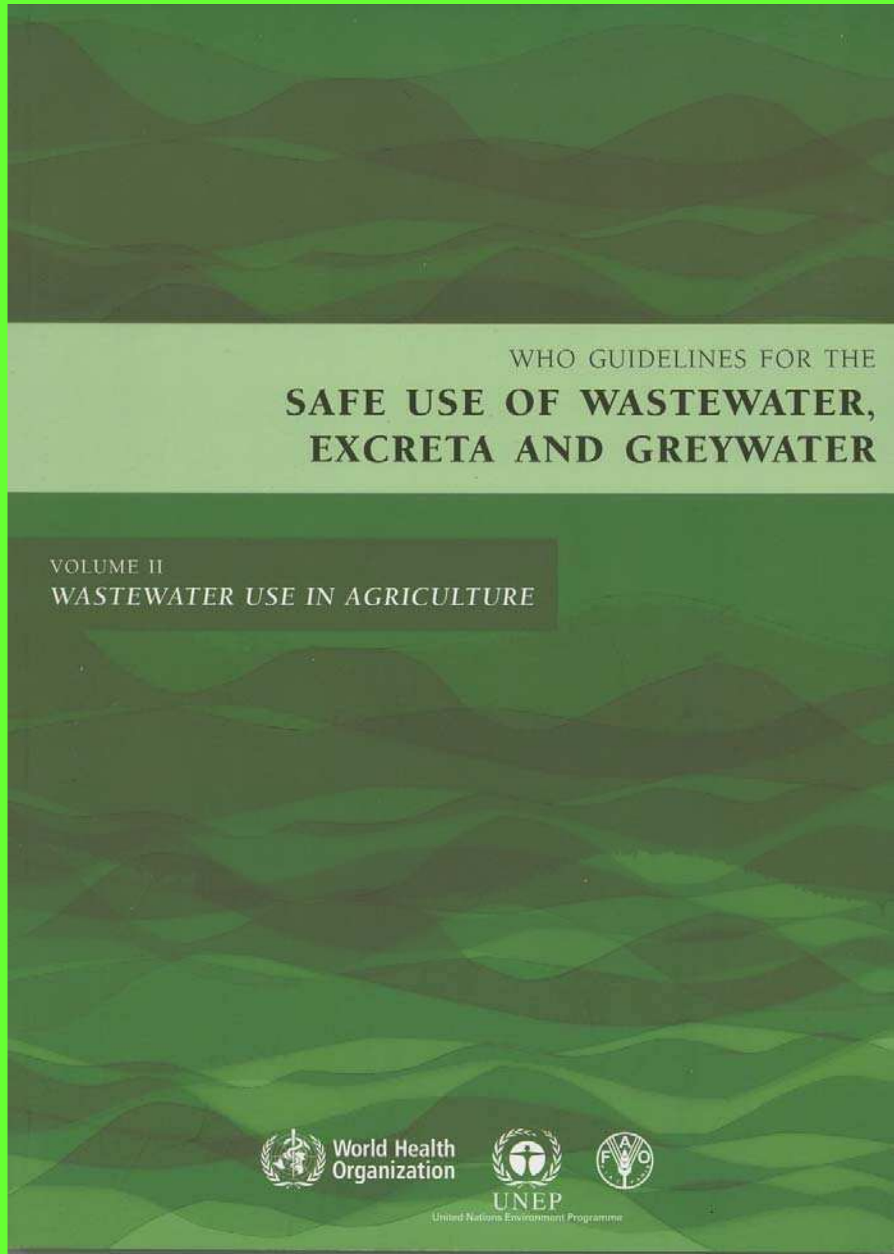
WHO 2006 Guidelines

A major change from the 1989 Guidelines

Now risk-based (QMRA)

Actually not so complicated!

➢ <u>Less</u> wastewater treatment needed for unrestricted irrigation



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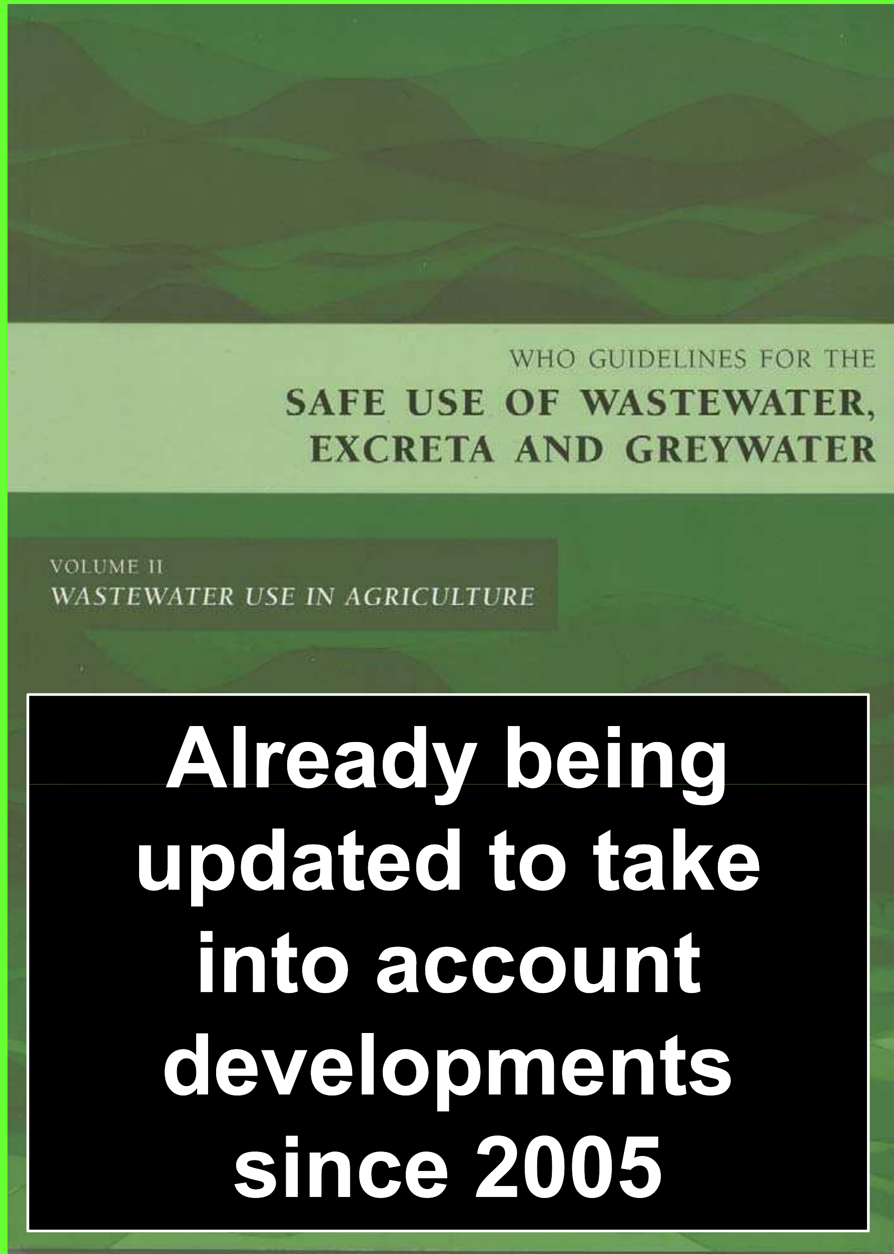

Already being updated to take into account developments since 2005

ASCARIS

- For 10^{-5} DALY loss pppy, the tolerable *Ascaris* infection risk is ~10^{-3} pppy
- In hyperendemic areas this is achieved by a 4-log unit *Ascaris* reduction (from 1000 epl to 0.1 epl)
- BUT only 2 log units through treatment (1-d anaerobic pond + 5-d facultative pond) as:
- 2 log reduction by peeling

Median *Ascaris* infection risks for children under 15 from the consumption of wastewater-irrigated raw carrots estimated by 10,000-trial Monte Carlo simulations*

Number of *Ascaris* eggs per litre of wastewater	Median *Ascaris* infection risk pppy	Notes
100–1000	0.86	Raw wastewaters in hyperendemic areas.
10–100	0.24	Raw wastewaters in endemic areas.
1–10	2.9×10^{-2}	Treated wastewaters.
1	5.5×10^{-3}	Wastewater quality required to comply with the 1989 and 2006 WHO Guidelines.
0.1–1	3.0×10^{-3}	Highly treated wastewaters.
0.1	5.5×10^{-4}	Wastewater quality recommended by Blumenthal *et al.* (2000).
0.01–0.1	3.0×10^{-4}	Treated wastewaters in non-endemic areas.

*Assumptions: 30–50 g raw carrots consumed per child per week (Navarro *et al.* 2009); 3–5 ml wastewater remaining on 100 g carrots after irrigation (Mara *et al.* 2007); N_{50} = 859 ± 25% and α = 0.104 ± 25%; no *Ascaris* die-off between final irrigation and consumption.

WSP: The Future

Carbon capture & bio-energy

253 © IWA Publishing 2008 Water Science & Technology—WST | 58.1 | 2008

Solar-powered aeration and disinfection, anaerobic co-digestion, biological CO_2 scrubbing and biofuel production: the energy and carbon management opportunities of waste stabilisation ponds

A. N. Shilton, D. D. Mara, R. Craggs and N. Powell

Presented at IWA Congress in Vienna, September 2008


WESTERN TREATMENT PLANT, MELBOURNE
Covered part of anaerobic section of first pond
BIOGAS COLLECTION
Electricity generation:
6000 kW for 8-16 h/d, 365 d/year


WESTERN TREATMENT PLANT, MELBOURNE
Covered part of anaerobic section of first pond
BIOGAS COLLECTION
Electricity generation:
6000 kW for 8-16 h/d, 365 d/year
GREEN ENERGY
CARBON CREDITS
Clean Development Mechanism
in developing countries

WSP: The Future?

ALGAL BIOFUEL

CALIFORNIA: algae to jet fuel

Page last updated at 13:51 GMT, Thursday, 8 January 2009

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First flight of algae-fuelled jet

A US airline has completed the first test flight of a plane partly powered by biofuel derived from algae.

The biofuel's developers showcased its algal origins

The 90-minute flight by a Continental Boeing 737-800 went better than expected, a spokesperson said.

One of its engines was powered by a 50-50 blend of biofuel and normal aircraft fuel.

Wednesday's test is the latest in a series of demonstration flights by the aviation industry, which hopes to be using biofuels within five years.

The flight was the first by a US carrier to use an alternative fuel source, and the first in the world to use a twin-engine commercial aircraft (rather than a four-engine plane) to test a biofuel blend.

January 2009

50% normal aviation fuel and 50% biofuel (½ from algae and ½ from *Jatropha*)

US Department of Energy

Biomass Program

Algal Biofuels

Biofuels made from microalgae hold the potential to solve many of the sustainability challenges facing other biofuels today.

Algal biofuels are generating considerable interest around the world. They may represent a sustainable pathway for helping to meet the U.S. biofuel production targets set by the Energy Independence and Security Act of 2007.

Renewed Interest and Funding

Higher oil prices and increased interest in energy security have stimulated new public and private investment in algal biofuels research. The Biomass Program is reviving its Aquatic Species Program at the National

Benefits of Algal Biofuels

Impressive Productivity:
Microalgae, as distinct from seaweed or macroalgae, can potentially produce 100 times more oil per acre than soybeans—or any other terrestrial oil-producing crop.


www.biocycle.net
BIOCYCLE INTERNATIONAL CONFERENCE 2009
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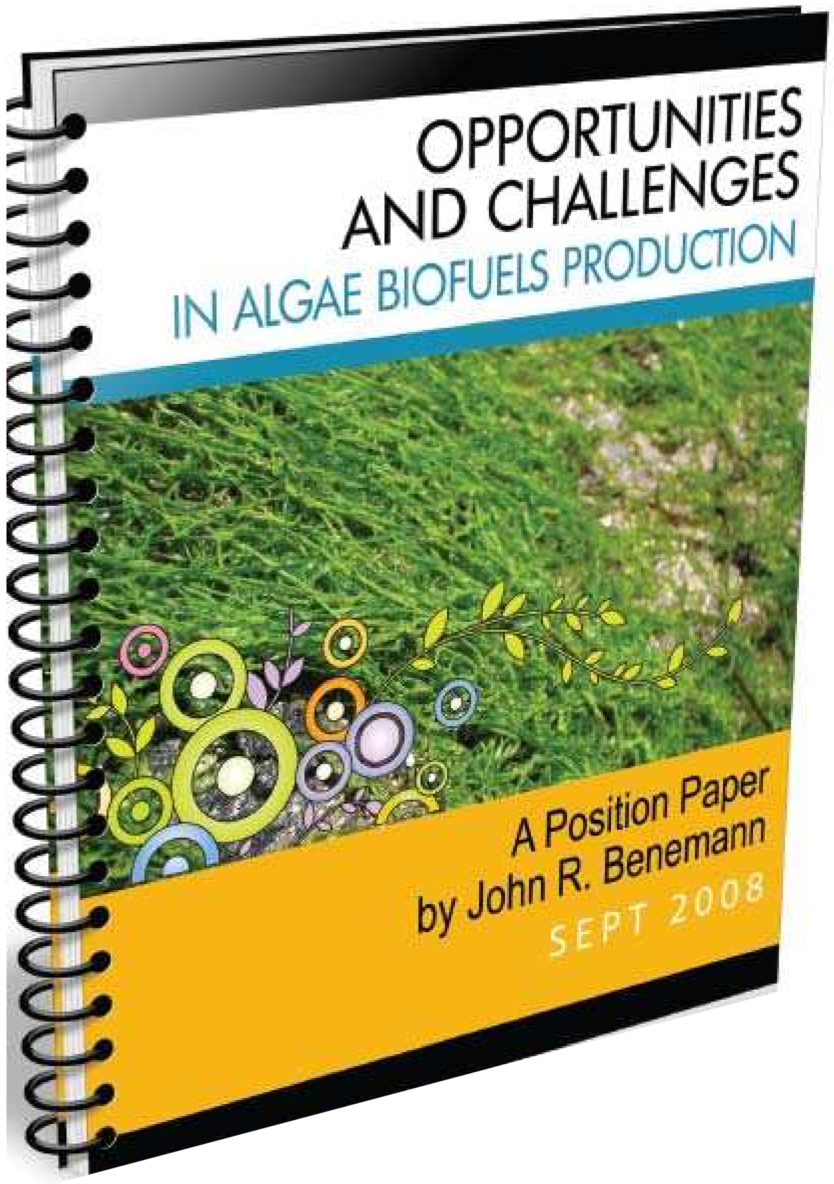
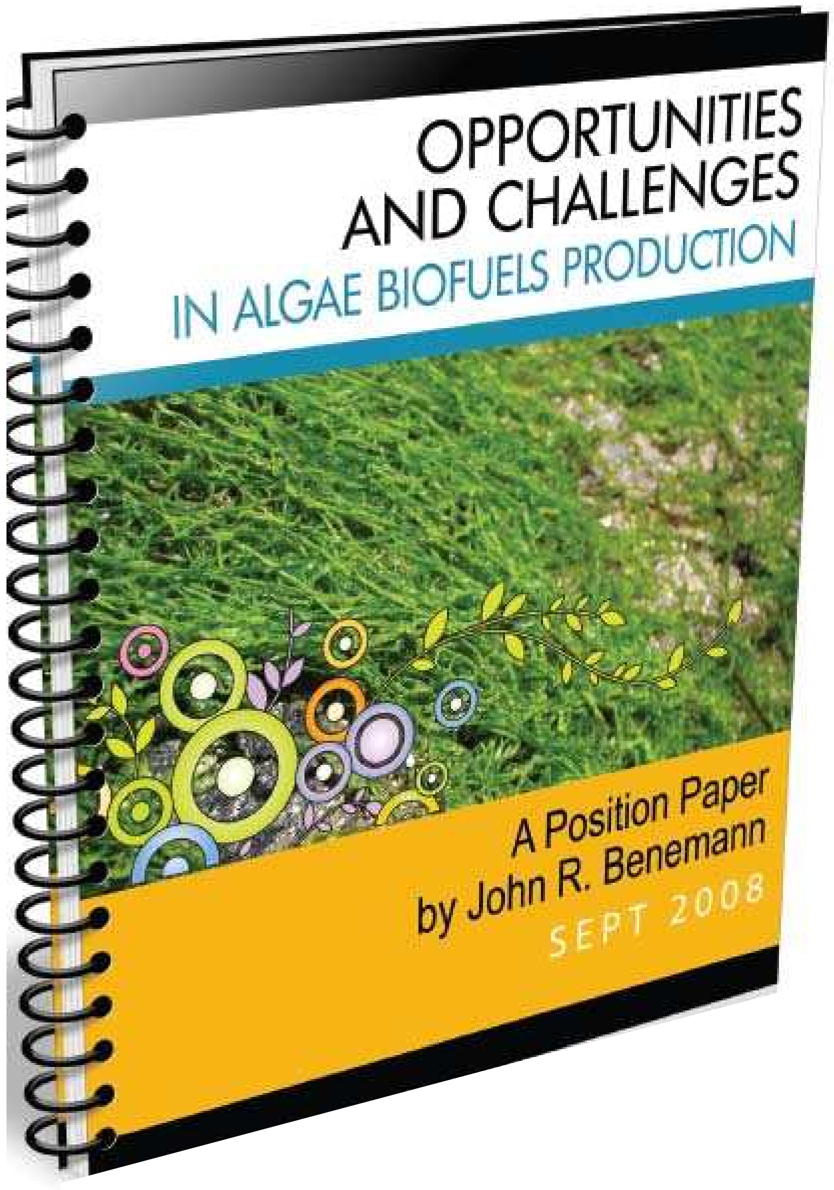
BIOCYCLE CELEBRATES 50 YEARS OF INDUSTRY LEADERSHIP
FEBRUARY 2009
BIOCYCLE
ADVANCING COMPOSTING, ORGANICS RECYCLING & RENEWABLE ENERGY
RENEWABLE FUELS
Cultivating Algae At Wastewater Treatment Plants
Photo bioreactors contain algae – fed with wastewater and carbon dioxide emissions – that will be harvested to produce biodiesel and animal feed.



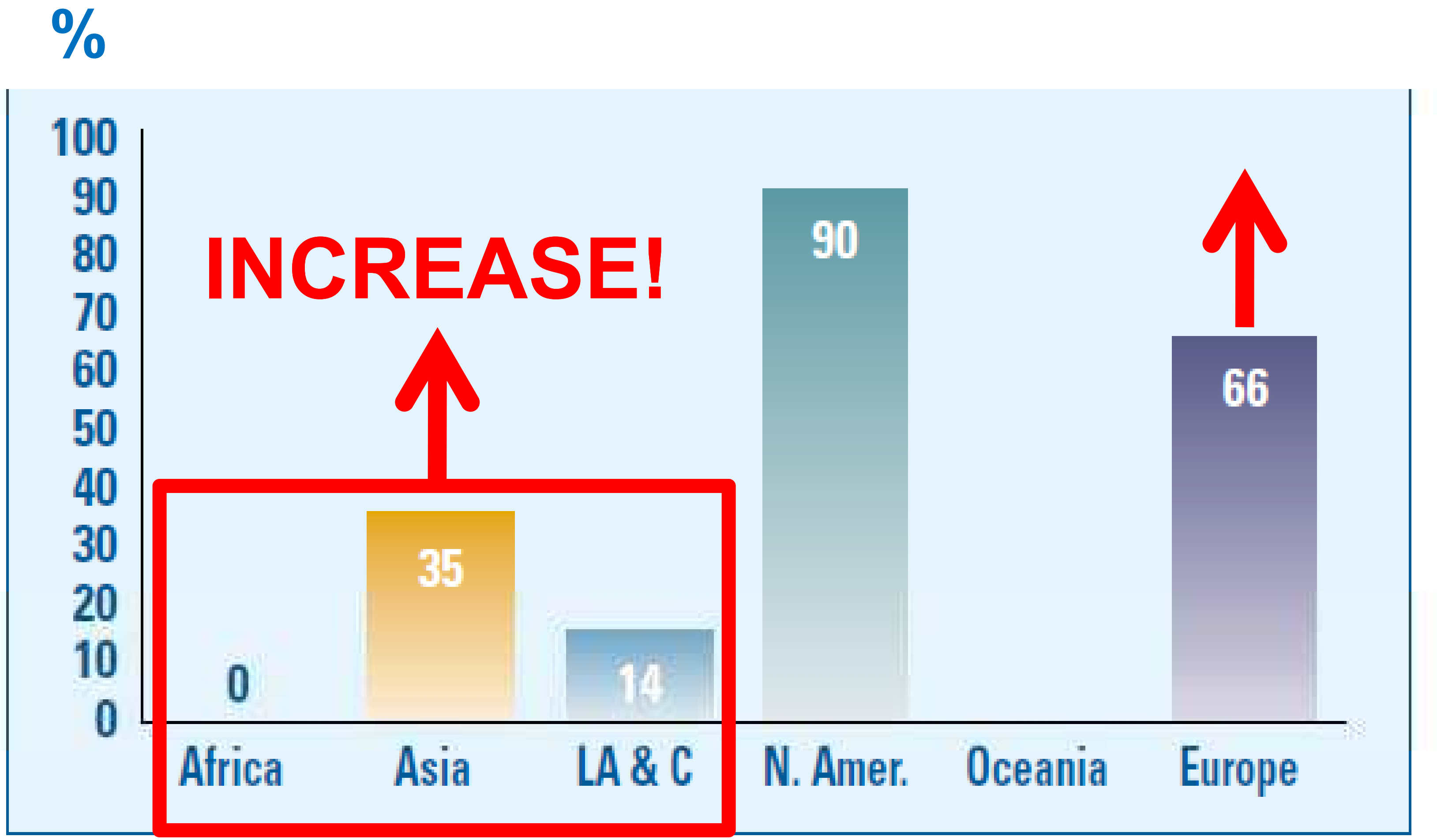
"The cultivation of microalgae for biofuels in general and oil production in particular is not yet a commercial reality and, outside some niche, but significant, applications in wastewater treatment, still requires relatively long-term R&D..."



WSP
(actually HRAP):
The Future

Clearly much
R&D
on algal biofuel
production!

But we must NOT lose sight of the 'basics'



Our Future:

We will need a world with more WSP and WSTR

Thank you!

Obrigado!