# developing the formulas

## easy modelling of NSP projects

by

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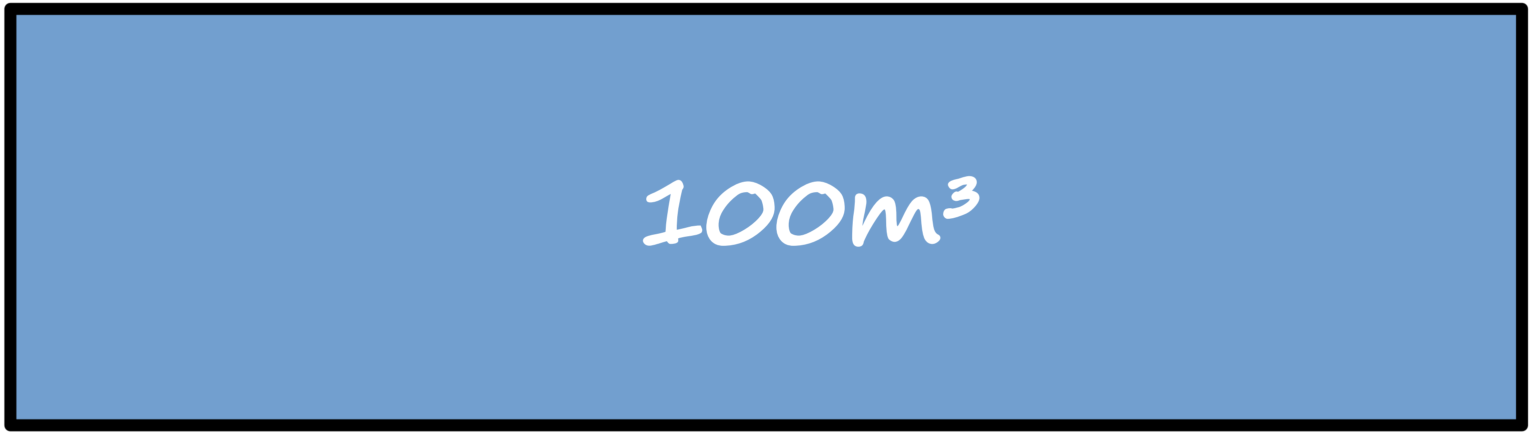
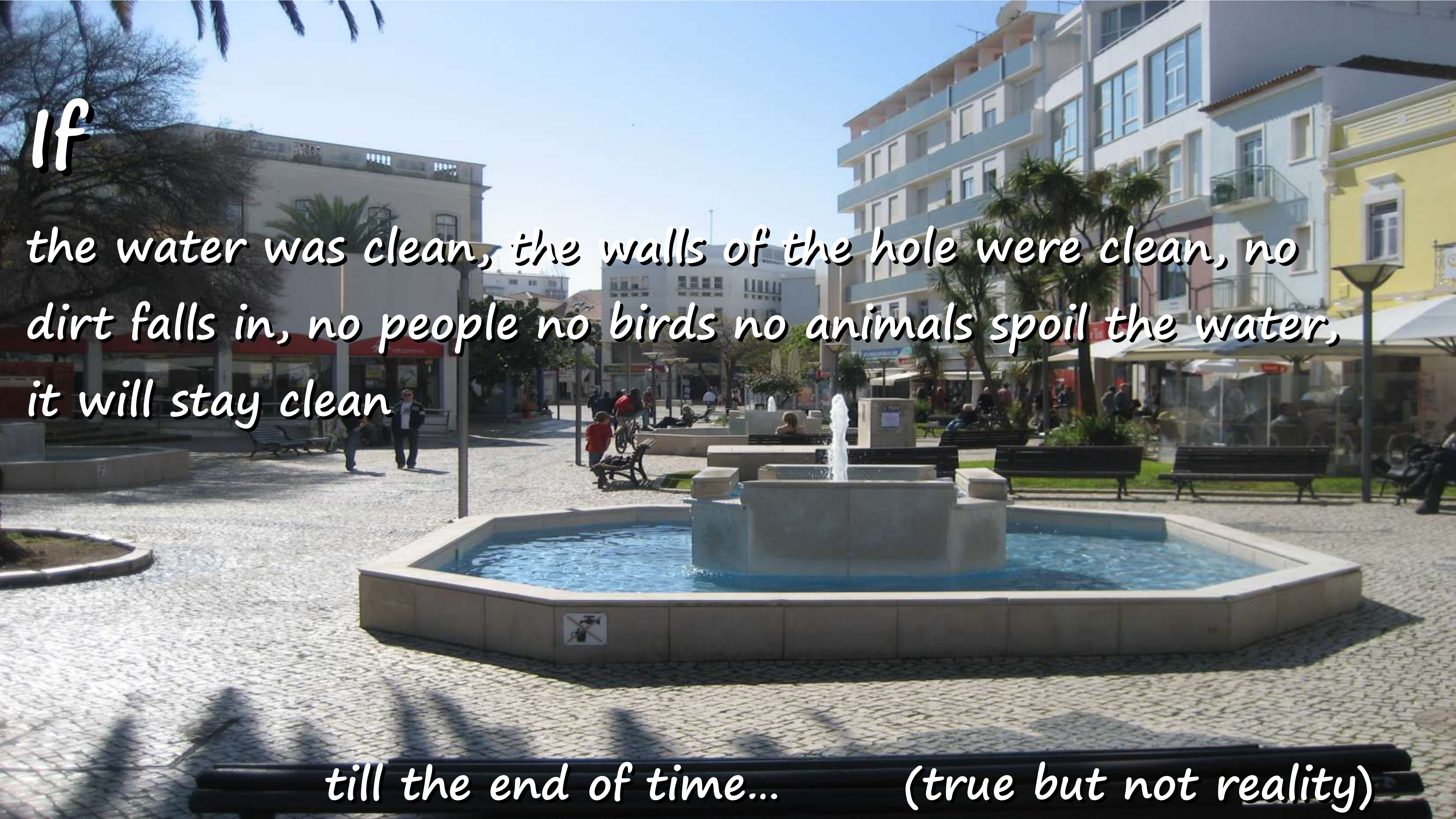
for the IOB in oct 2021 in Albufeira

# 1.) you dig a hole and fill it with water




what will happen?



# If

the water was clean, the walls of the hole were clean, no dirt falls in, no people no birds no animals spoil the water, it will stay clean

till the end of time... (true but not reality) the water is never clean,

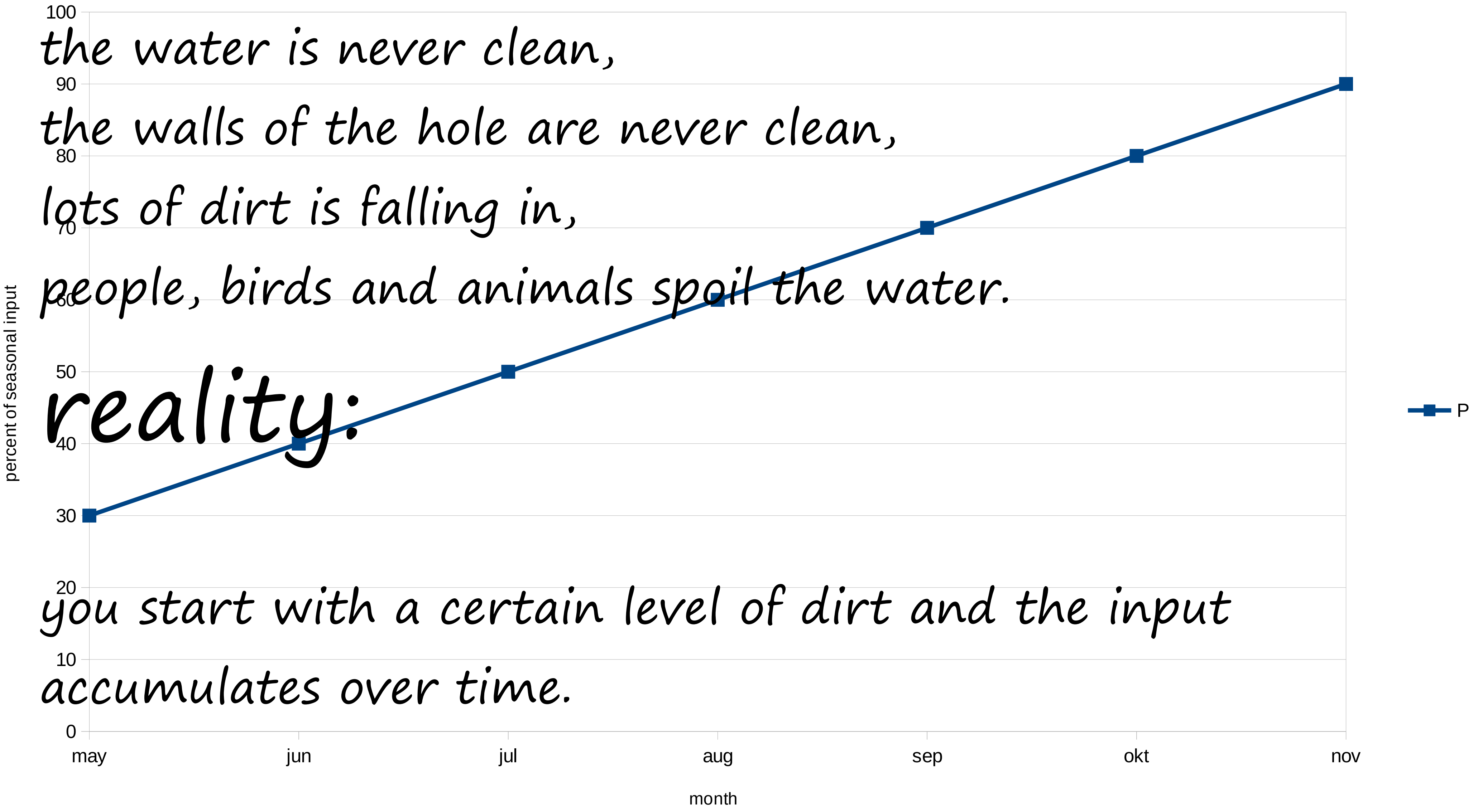
the walls of the hole are never clean,

lots of dirt is falling in,

people, birds and animals spoil the water.

# reality:

you start with a certain level of dirt and the input accumulates over time.



# you say dirt, you mean fertilizer

- dirt is made of
- organic material (C,N,H...P) and
- inorganic (Ca, Mg, K, Fe, Si... P) material.

these elements make a fantastic grow...

# you say fertilizer, mean phosphorus

- $C \rightarrow CO_2 \uparrow$ respiration (all creatures)
- $N \rightarrow N_2 \uparrow$ denitrification (denitrifying bacteria)
- $H \rightarrow H_2O \approx$
- $P \rightarrow PO_4^{3-}$ can not leave to atmosphere - accumulates!

  → feedstock for algae and bacteria

# Natural Pond / Pool means reasonable quantities of input ≠ sewage plant

- pre-condition 1:
  - less input of Carbon than creatures can degrade, more oxygen available than needed to build $CO_2$,
  - less input of N than biology can use or degrade.

# Natural Pond / Pool means living environment, not chlorinated or poisoned

- pre-condition 2:
  - no poisons!

pre-condition 1 & 2 ok

→ only P-problem is left to solve

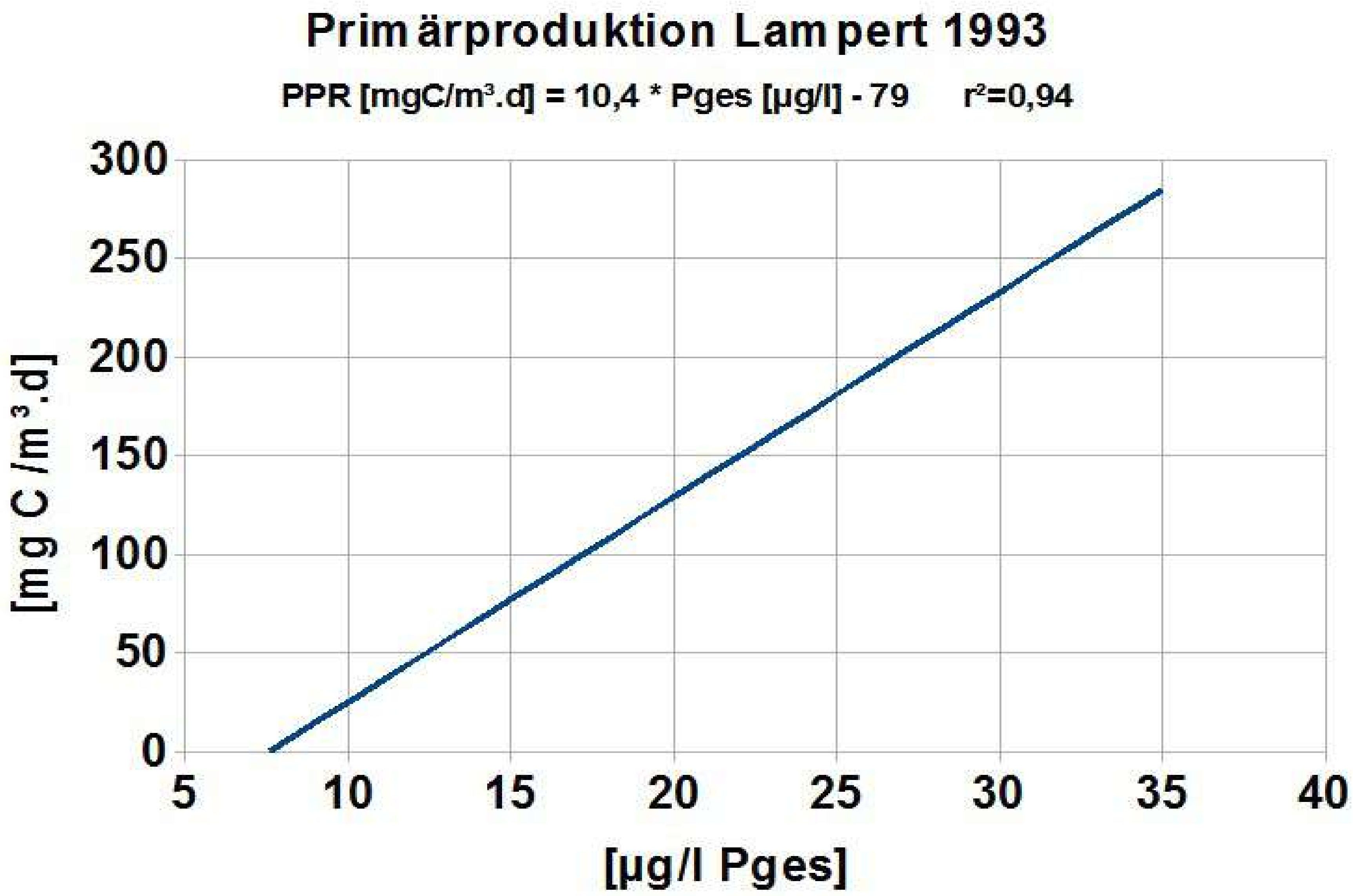
# Phosphorus limits primary production

- you know the quantity of P accumulated

  → you know how much biomass will grow

primary production

Lampert et al. 1993


Primärproduktion Lampert 1993
PPR [mgC/m³.d] = 10,4 * Pges [µg/l] - 79 r²=0,94
300
250
200
150
100
50
0
5
10
15
20
25
30
35
40
[mg C /m³.d]
[µg/l Pges]

# example

you fill our clean hole with clean water and nothing comes in except:

**1 person swimming every day**

how much algae biomass will be produced?

how much sediment will be formed?

# PÄP

the persons equivalent phosphorous (PÄP) is the average input of 1 user (swimmer, bather)

**1 PÄP = 100 mg P per person and day**

so in our 100m$^3$ indoor-pond-example 1 person is swimming every day, brings in 100mg P every day...

# Redfield OECD

in an natural environment (lake)

carbon $\propto$ nitrogen $\propto$ phosphorus

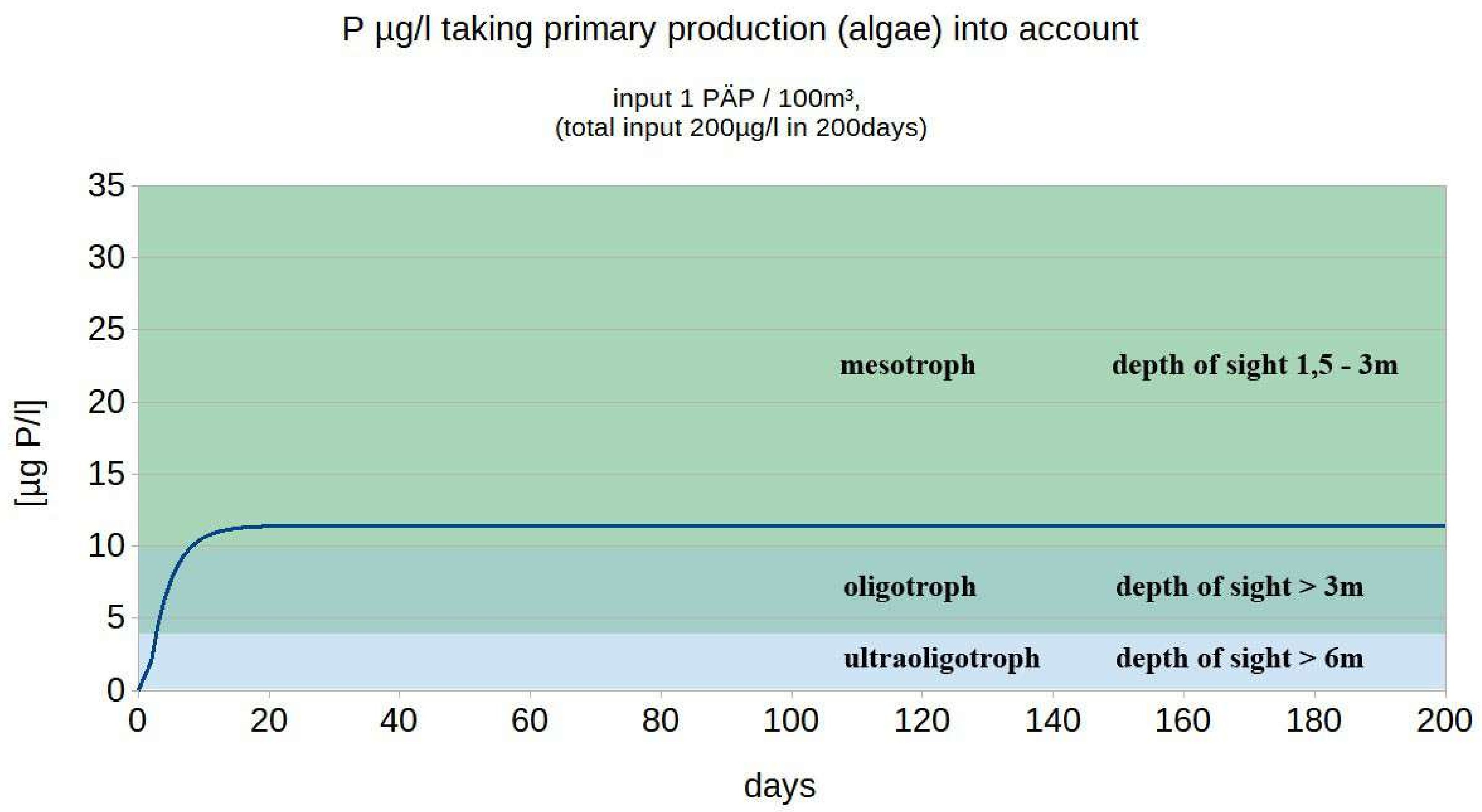
$\propto$ biomass $\propto$ chlorophyll $\propto$ depth of sight

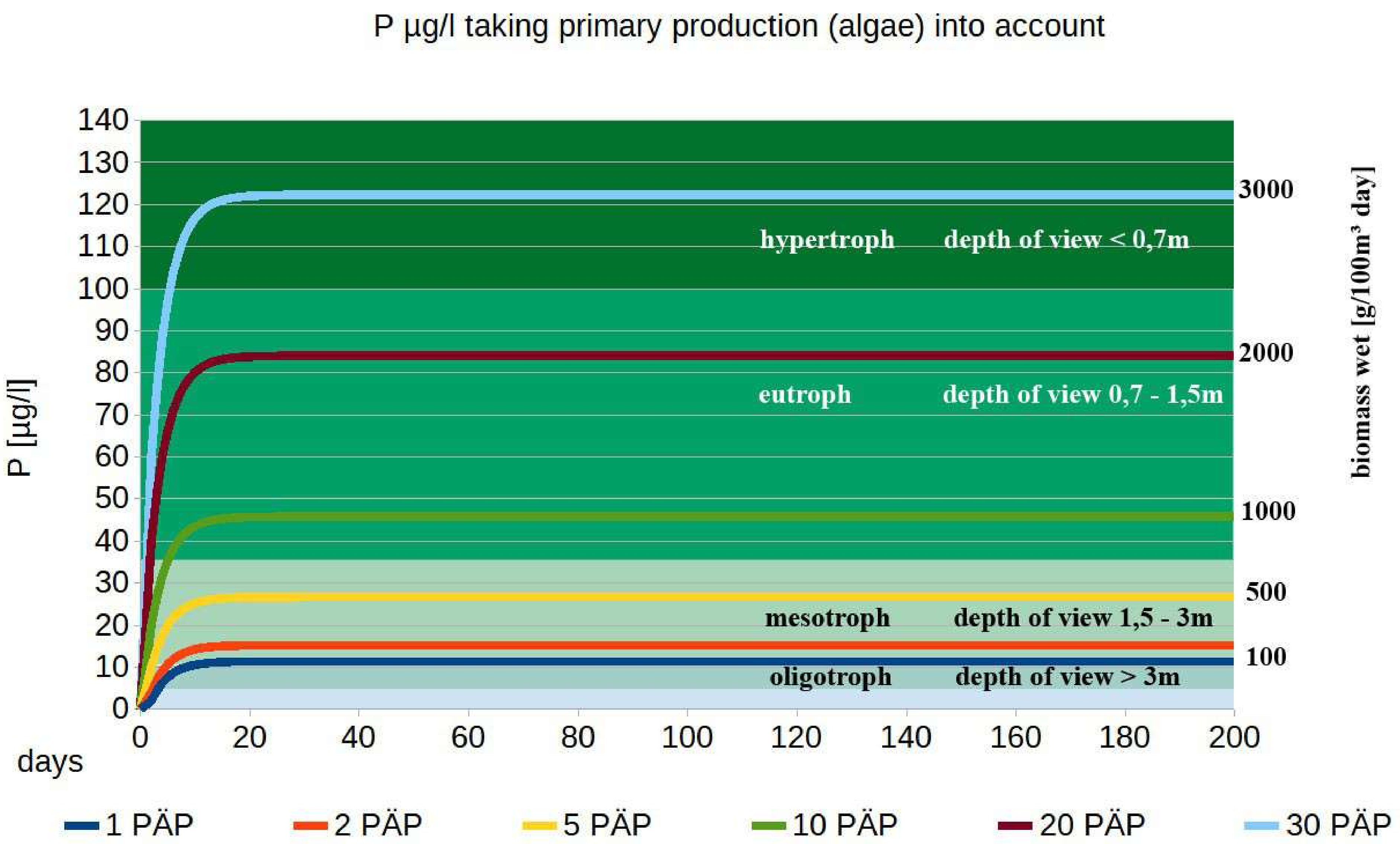
$\propto$ trophy $\propto$ bacteria count $\propto$ zooplankton

- $\propto$ sign stands for "is proportional" example: phosphorus $\propto$ carbon: P = (C/(106x12))x32

  (molar ratio C:N=106:1 molar weight C=12 molar weight P=32)P [g] = 39,78 C [g]

- example: phosphorus $\propto$ biomass wet: Px1000 ≈ biomass wet (analysis)


P µg/l taking primary production (algae) into account
input 1 PÄP / 100m³,
(total input 200µg/l in 200days)
[µg P/l]
35
30
25
20
15
10
5
0
mesotroph
depth of sight 1,5 - 3m
oligotroph
depth of sight > 3m
ultraoligotroph
depth of sight > 6m
0
20
40
60
80
100
120
140
160
180
200
days



P µg/l taking primary production (algae) into account
P [µg/l]
days
biomass wet [g/100m³ day]
hypertroph
depth of view < 0,7m
eutroph
depth of view 0,7 - 1,5m
mesotroph
depth of view 1,5 - 3m
oligotroph
depth of view > 3m
3000
2000
1000
500
100
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
0
20
40
60
80
100
120
140
160
180
200
1 PÄP
2 PÄP
5 PÄP
10 PÄP
20 PÄP
30 PÄP

# swimming pond

idea of the swimming pond:

**grow algae and produce sediments**

...and take out the sediments occasionally

# example

you fill our clean (indoor)hole with clean water and nothing comes in except:

**7 person swimming every day**

you can expect 34µg P, this leads to

| | | |
|---|---|---|
| 696g | biomass wet / 100m³ per day | |
| 7 kg | in | 10 days |
| 70 kg | | in 100 days |
| **140 kg** | **biomass (wet)** | **in 200 days** |

# 7 PÄP – how many persons?

PÄP = 100mg P per day

- can be a person
- can be input from filling water
- can be input from surroundings
- can be input from building materials

# i don't want sediments

if you can live with sediments, and have a moderate input of P, the natural pond is perfect

if you have more input or don't want the sediments:

- put in a pump….?

# algae swimming pond

you put in a pump and make the water flow

**→ from plankton to filamentous algae**

- clean water, no sediments
- algae biomass sticks on the wall (7 PÄP → 140kg algae/a) , plants pass away

# mechanical filtration swimming pond

put in a pump and a perfect mechanical filter, filter out the plankton (2,78kg every day), not move the water along any wall...→ swimming-pond with less sediments, but still green .

**you need to grow algae to filter them out!**

- no improvement in depth of sight (≙ sedimentation pond)
- no increased load possible (≙ sedimentation pond)

# clean water, no sediments, no algae

you grow algae outside the pond

you grow biofilm outside the pond

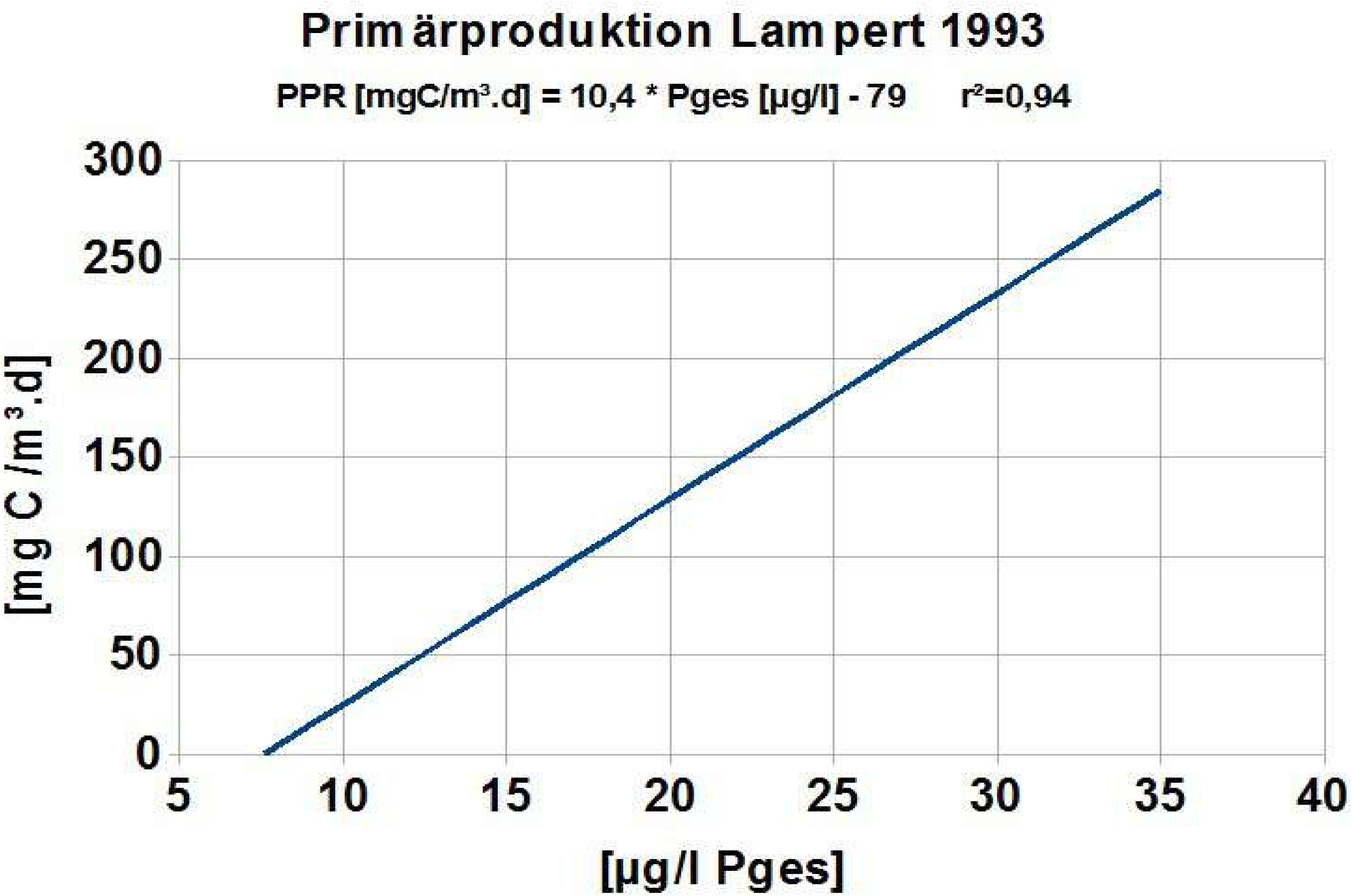
→ you lower P concentration in the pool

# Natural (water-treatment) pool

goal:

stay under 10µg/l P

→ nearly no algae, nearly no sediment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[mg C /m³.d]
300
250
200
150
100
50
0
5
10
15
20
25
30
35
40
[µg/l Pges]

# stay under 10µg/l P

- lower the input (filling water, building materials, surroundings input, (swimmers?))
- add more external biological filters

# Natural Swimming Pool – Biofilter

move water along a surface

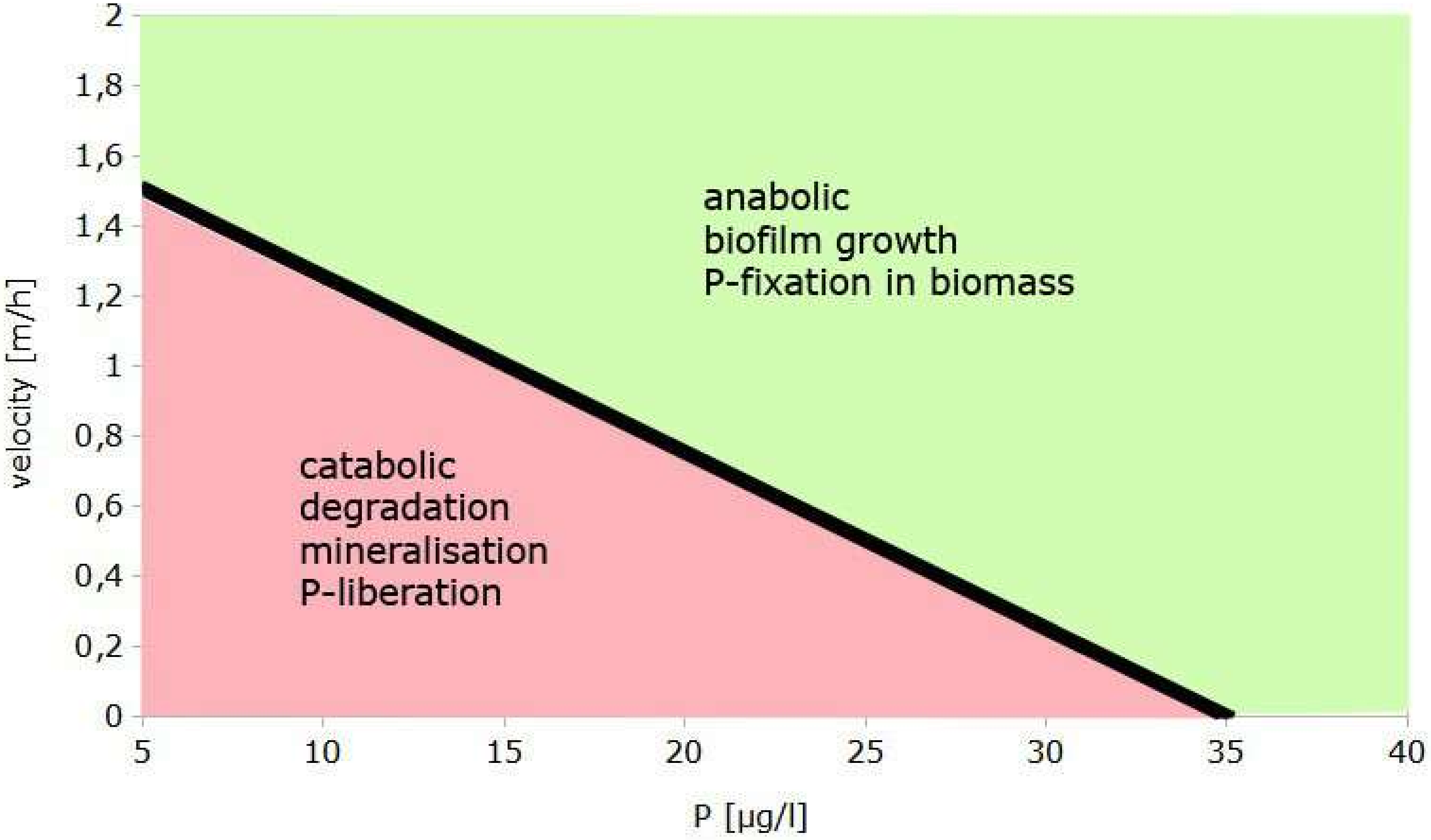
→ biofilm will grow how much?

**biofilm ∝ (P x velocity x surface x time)**

# Natural Swimmimg Pool - Biofilter

- at low nutrient levels biofilm needs flow just to survive
- if the velocity is higher, biofilm is growing
- if the velocity is lower, biomass will degrade

# biofilm metabolism (P-limitation)



# Biofilter for Swimming Pond

slow biofilter

degradation of biomass to nutrient solution

→ need of big sedimentation zone (plants)

→ or algae (or mix 🙁)

# Biofilter for Natural Swimming Pool

= fast biofilter

idea: build up biomass to bind P

→ <u>need of volume to store biomass</u>

(7PÄP = 140kg biomass / 200 days)

input → = biomass → = output

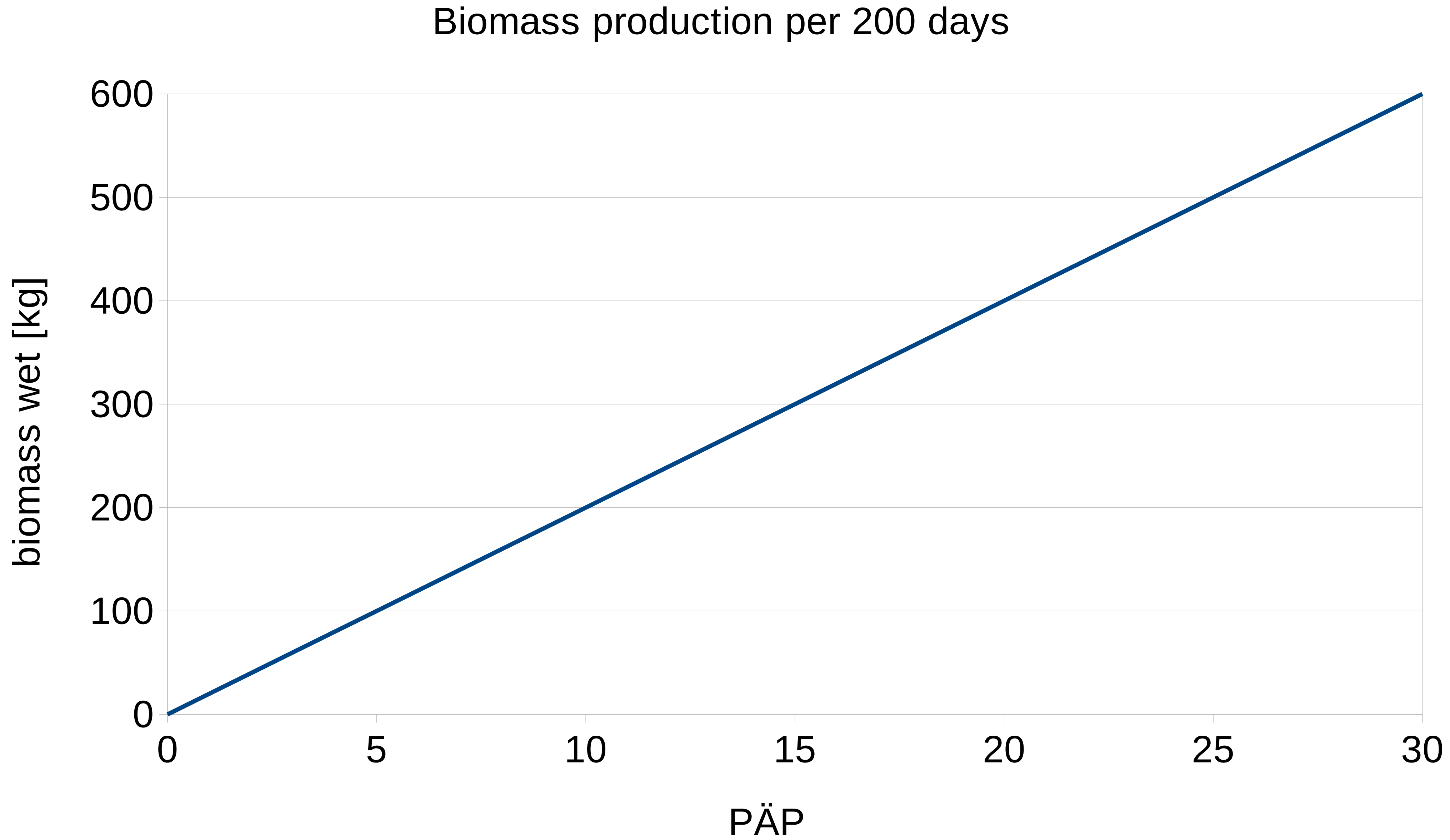
# Pool-Biofilter size

how much space do I need for biomass?

- PÄP $\propto$ biofilm-biomass

1PÄP (100mg P/d) =

0,1gP x 1000 x 200d= 20.000g = 20kg/a


Biomass production per 200 days
biomass wet [kg]
0
100
200
300
400
500
600
0
5
10
15
20
25
30
PÄP

# storage conditions biofilm

<u>biofilm needs oxygen</u>

→ no oxygen → set P free

<u>needs food</u>

→ no food → set P free

→ → large area for delivery by water

# $2m^3$ gravel / $10m^3$ water

for a stable installation we take 2 $m^3$ gravel per $10m^3$ water and 1 person. That equals 4 PÄP:

≈ 2 PÄP (for 1 person and input)

+ 2 PÄP reserve (you will need for stable operation!)

# 2m/h velocity

for a stable installation you should provide 2m/h water velocity or more on the surface of the gravel, to ensure the biofilms needs.

# real velocity, relative water/surface

velocity [m/h]:

- your pump delivers a water volume (measure it!)
- your gravel has a free volume for the water of about 1/3 if you have nearly 1 size gravel. So the velocity in the gravel is 3 times the theoretical velocity without gravel.

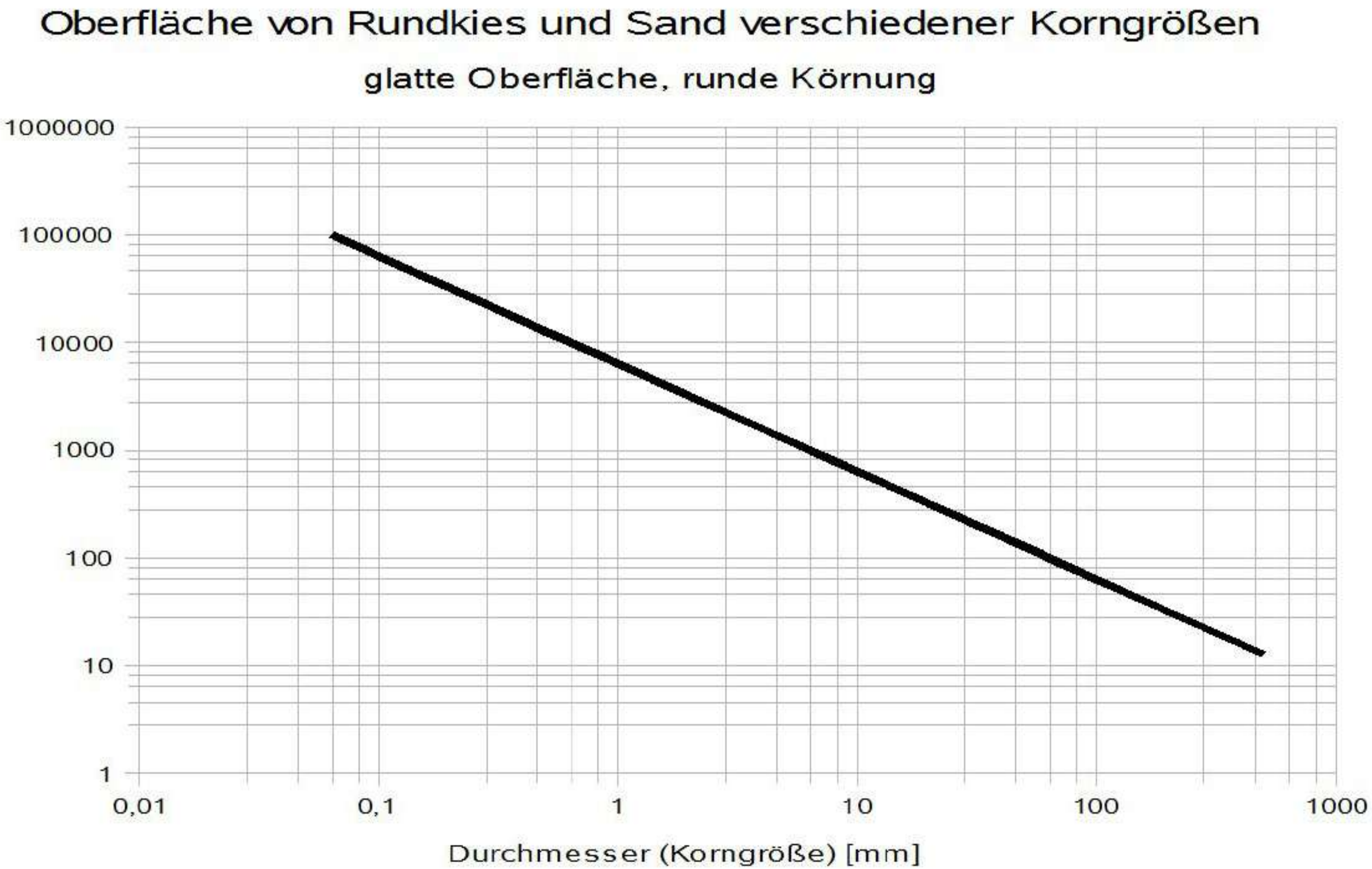
# calculation        goal: ≤ 10µg/l P

**biofilm ∝ (P x velocity x surface x time)**

P: we want to know the biofilm-production at 10µg/l P

(1000 times less than in a sewage plant!)

# surface [m²/m³]



# example

gravel:

6-8mm surface $1000 m^2/m^3$ 28% free volume

$10 m^2$ bottom up filter, 2m high

how many PÄP?

# example

$1000 m^2/m^3$ = surface

($10 m^3$ pump / $10 m^2$ area / 0,28 free vol) – 1,2m/h base-biofilm-metabolism = 2,371 m/h velocity

10m x 2m = $20 m^3$ volume

ASC-Filterkennzahl = 1.000 x 2,371 x 20 = 47.430

# example

ASC-Filterkennzahl = 47.430

[mgP/h] = ASC-Filterkennzahl / 320 (constant determined from practice)

[mgP/d] = [mgP/h] x 24 (1 day 24 hours)

PÄP = [mgP/d] /100 (100mg P/d = 1 PÄP)

→ PÄP = ASC Filterkennzahl / 1333 = 35,5 PÄP

→ might be perfect for a clean built 100m³ outdoor-pool used by 8 people

# end

this is not the end but the beginning

love to biological mathematics...

→ follow us

# Fast calculator

biofilm wet [g] =

P [g] x 1000

C [g] x 25

P[g]:C[g] = 1:40 (P[mol]:C[mol]=1:106)

# Fast calculator

1 t

- 1000kg
- 1000x1000g
- 1000x1000x1000mg
- 1000x1000x1000x1000μg

æ (middle aged ligature a+e)

was used for latin aequalis æ

from this derived: equal $=$

proportional $\propto$ also $\sim$ is proportional

approximately $\approx$ corresponds to $\triangleq$

identical $\equiv$