# Workshop Aquaponic

PRO Arkades

PAKSE, 2010-12-06

# Business requirements for operating aquaculture and hydroponic facilities (Aquaponic) in Laos

| | |
|---|---|
| *Organised by:* | **LITSE**<br>Lao State International Trade and Services Enterprise, Vientiane / Laos<br>and<br>**Pro Arkades**<br>GaLaBau und Sanierungs- GmbH<br>Berlin / Germany |
| *Local partners:* | Ourworld rural development Co. Ltd. Vientiane / Laos<br>Neo Siam Biz, Bangkok / Thailand<br>IBAU – Ingenieurbüro für Aquakultur und Umwelttechnik Berlin / Germany<br>IBP – Ingenieurbüro Dr. Frank Panning Berlin / Germany |

# Business requirements for operating aquaculture and hydroponic facilities (Aquaponic) in Laos

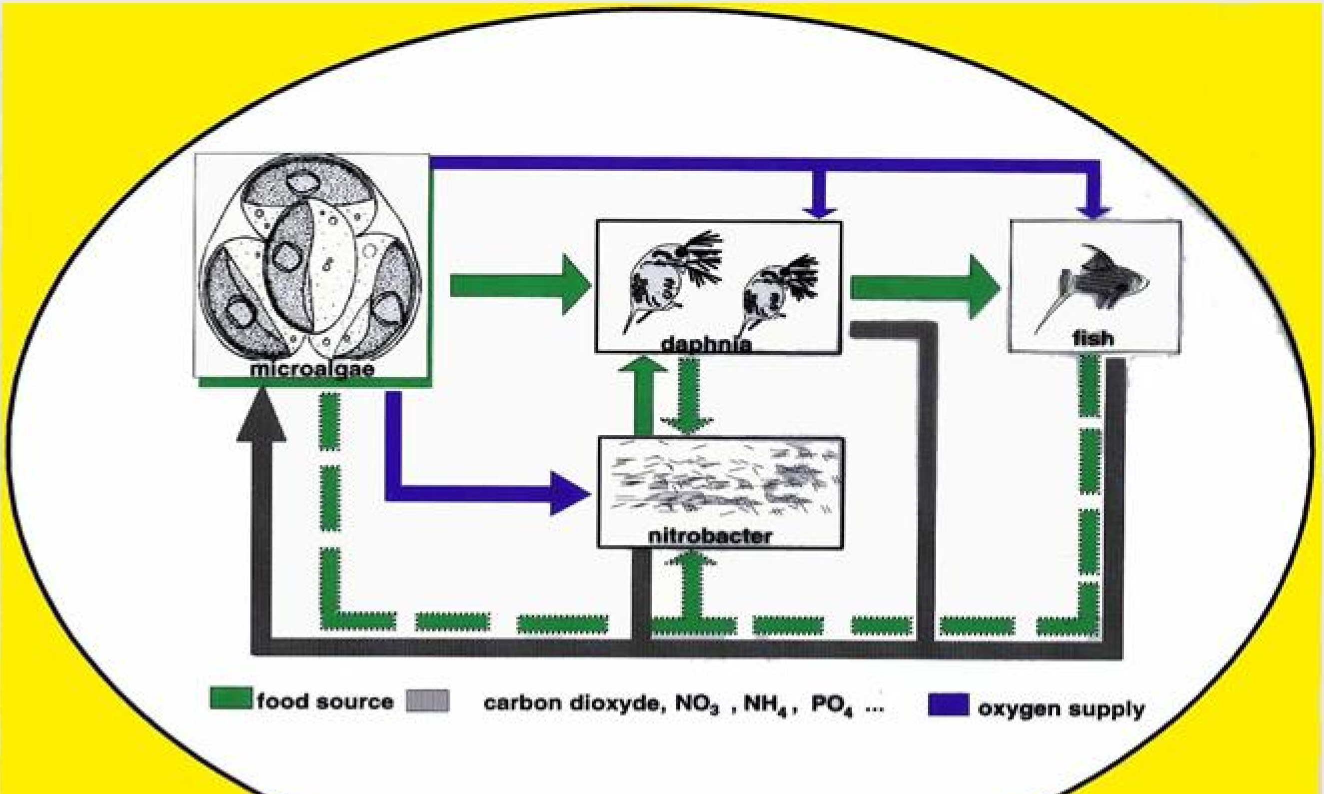
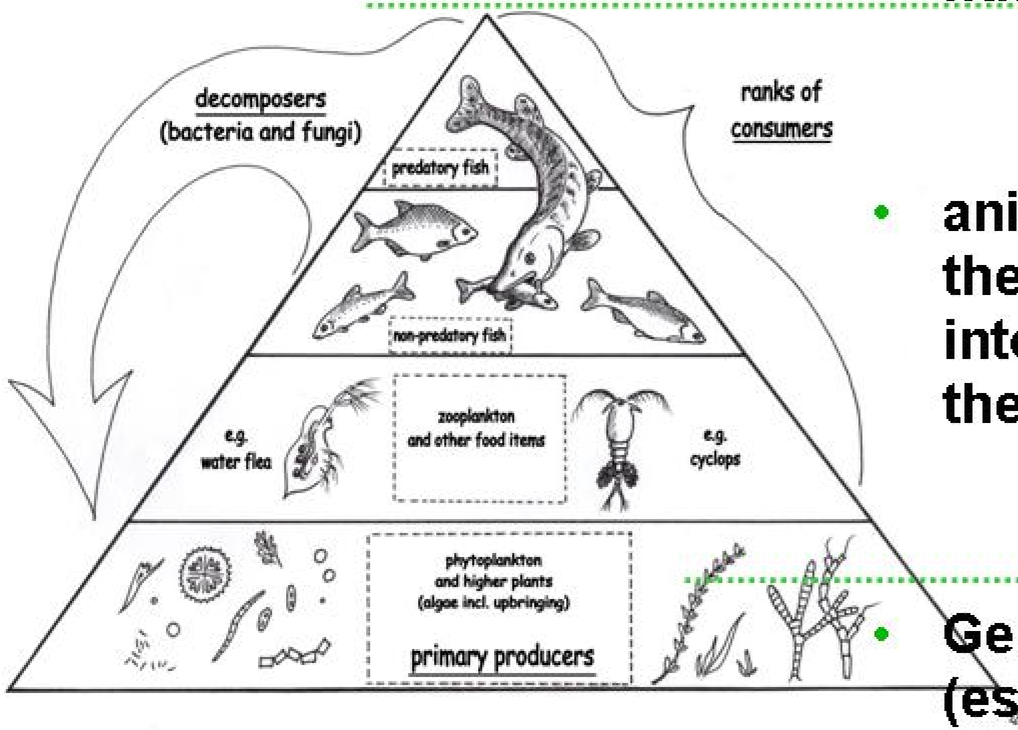



Abb. : Closed Food Chain




- Dead biomass serves as nutrition for decomposers
- animals are classified by their consumer function into different categries of the food chain
- Generation of biomass (especially as by plant as primary producers)



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# Business requirements for operating aquaculture and hydroponic facilities (Aquaponic) in Laos

## I. water

1. water cycle
2. water use, water storage and treatment
3. water parameters and analysis of parameters
4. close nutrient cycle

## II. fish

1. habitat
2. respiration of the fish, oxygen and nitrogen budget
3. nutrition
4. breeding
5. hygiene

## III. hydroponic

1. choice of plants
2. habitat require-ments of plants

## IV. practice

1. functioning of pilot facility
2. practical appliance


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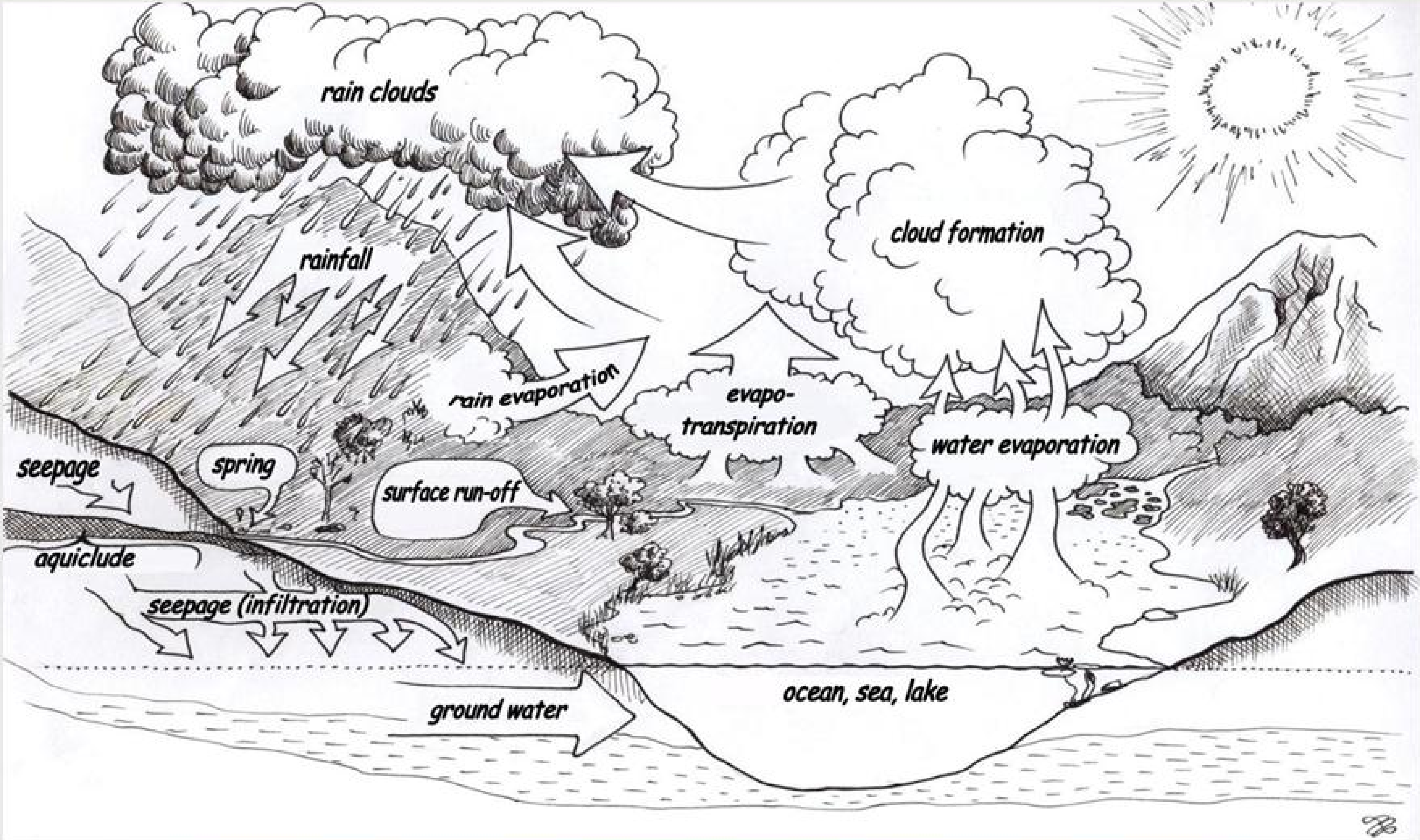
1. water cycle

2. water use, water storage and treatment

3. water parameters and analysis of parameters

4. closing nutrient cycles



rain clouds
cloud formation
rainfall
rain evaporation
evapo-transpiration
water evaporation
seepage
spring
surface run-off
aquiclude
seepage (infiltration)
ground water
ocean, sea, lake

- **characteristics of water**
  - solvent for gases (significant for fish)
  - dependancy on temperature, pressure and acidity
  - $O_2$
  - N gas bubble disease
  - $CO_2$ kidney damage
  - $H_2S$ neurotoxin

- **oxygen**
  - solubility dependent on temperature

| Water temperature °C) | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
|---|---|---|---|---|---|---|---|
| Amount of oxygen (mg/l) | 14,2 | 12,4 | 10,7 | 9,8 | 8,8 | 8,1 | 7,5 |

  - in water available amount of oxygen accounts to 3% in saturated conditions
  - current flow / aeration effects 100% oxygen saturation
  - oxygen requirement of fish (percental solubility)
    - requirement increases with rising temperatures
    - optimum: **5 – 30 mg/l**
  - oxygen requirement of plants
    - plants need oxygen for root
    - optimum oxygen supply increases nutrient uptake by plants

- **solution of ions**
  - plant nutrients
    - N, P, K
  - Immission through fish fodder and fish excrements

| Nutrient concentration of: | N | P |
|---|---|---|
| in fodder | 6 % | 1 % |
| in fish | 3 % | 0,5 % |
| in pond water | 3 % | 0,5 % |
| in excrements | 0,6 % | 0,3 % |
| In water /urine | 2,4 % | 0,2% |

  - Constant water exchange → water body = transport of suspended matter, nutrients, and organic material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## Assessment of water quality through analysing physical, chemical, and biological parameters

**temperature**

→ rising water temperatures amplifies fish metabolism and increases need for oxygen

**Depht visibility**

→ criterion for in water suspended particles (i.e. biomass and mineral substances)

**oxygen concentration**

→ amount of oxygen in solution (mg/l) depends on water temperature

**pH-value**

→ criterion for acidic and basic reaction of water (scale 0 to 14)

**determination of water quality by means of bioindicators**

**plants**

- **Physical parameters**

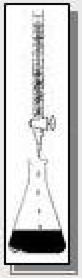
temperature

- conditions:
  - ⇨ Optimum conditions for tilapia between 24 … 30 °C
  - ⇨ Pre-condition: oxygen supply and optimum feeding
  - ⇨ Avoidance of sudden temperature change: approach to max. 2 °C per day
- Determination by thermometer

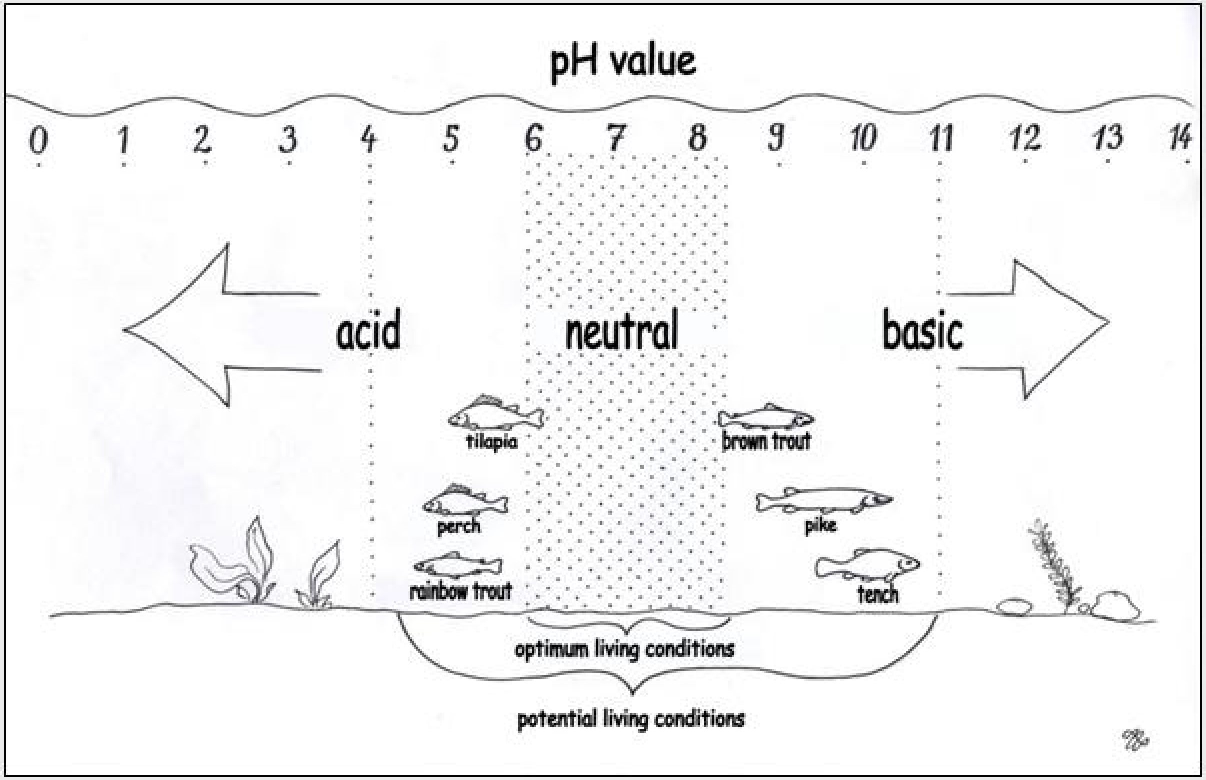
visibility depth

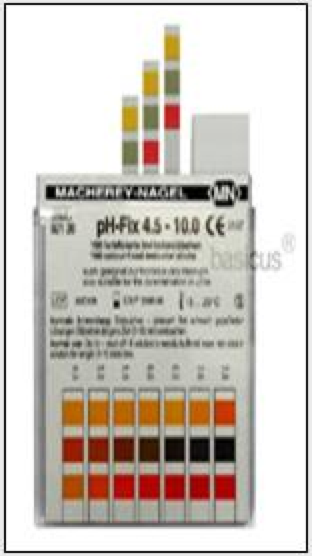
- conditions:
  - ⇨ estimation, of how far sunlight can penetrate into
    = pre-condition for growth of underwater plants
- determination:
  - ⇨ by Secchi-disk → visibility = immersion depth of disk until becoming invisible

- **Chemical parameters: oxygen content**
  - conditions:
    - ⇨ availability of ample oxygen supply determines growth, health, Gesundheit, reproduction and survival of fish
    - ⇨ Best pre-conditions for fish (i.e. tilapia): **7,5 mg/l to 9 mg/l**
    - ⇨ Water pollution leads to anaerobic conditions with low oxygen availability
    - ⇨ Missing oxygen causes poor fodder utilization, growth depression, disease, loss in fish population
    - ⇨ Reduction or cessation of feeding in case of oxygen deficit
    - ⇨ measure for oxygen enrichment: aeration
  - determination: winkler test or electronic measurement (Clark-electrode)



- **Chemical parameters: pH-value**
  - conditions:
    - ⇨ Optimum conditions for fish growth: ph 6,0 to ph 8,5



- **other relevant parameter:**
  - BOD (biochemical oxygen demand)
  - COD (chemical oxygen demand)
  - $NH_4$ < 1 mg/l
  - $NO_2$ < 1 mg/l
  - $NO_3$ 100 ... 200 mg/l
  - $PO_4$ < 50 mg/l
  - $CO_2$ < 15 mg/l

1. Fish habitat

2. Fish respiration, oxygen and nitrogen budget

3. Fish nutrition

4. Fish breeding

5. Fish hygiene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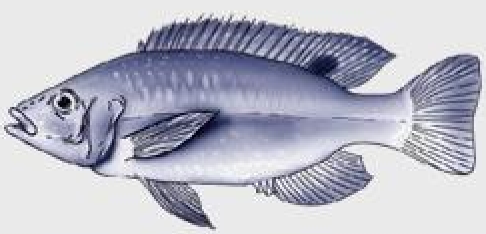
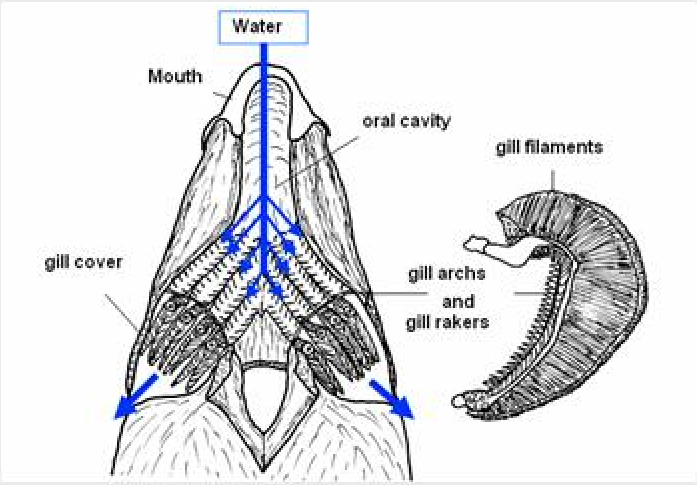
# HABITAT OF THE FISH

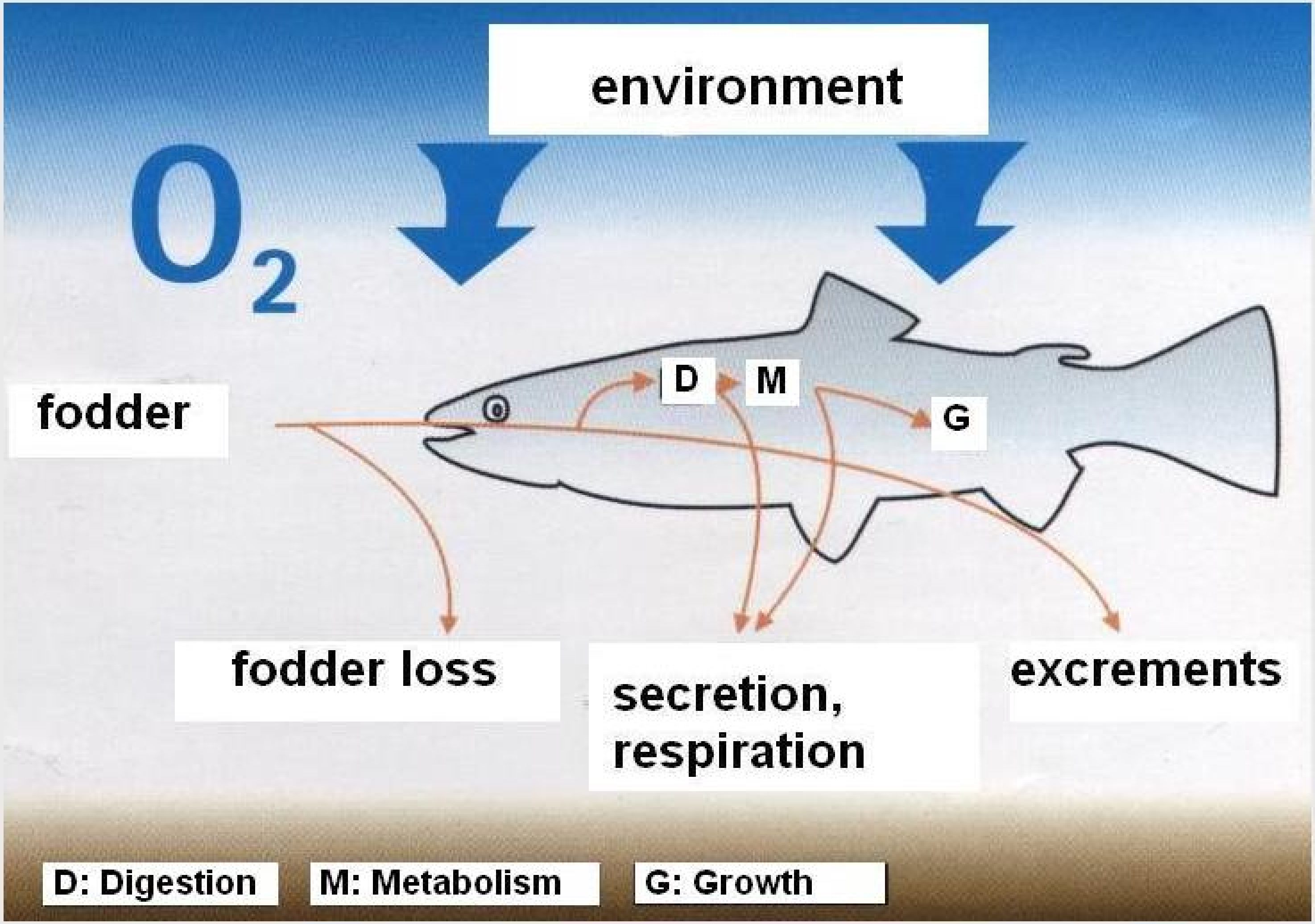
- **Fish live in almost every waters on earth**
- **Habitat in fresh waters as well as in saline waters**
- **Knowledge about natural fish habitat = most important pre-condition for successful and species-appropriate breeding**

- **example tilapia:**
  - Chichlid family
  - Native in tropical and subtropical regions of Africa, South America, and Asia (i.e. Laos)
  - Adapted to water temperatures between 20 °C and 30 °C



- **Respiration of fish / oxygen budget:**
  - Oxygen is solved in water
  - Uptake of water through gills
  - by regularly opening and closing their mouths fish induce in inflow of water
  - Oxygen contents in waters are variable: some fish species need oxygen rich waters, others, especially fresh water fish, are adapted to lower oxygen contens





environment
$O_2$
fodder
D
M
G
fodder loss
secretion, respiration
excrements
D: Digestion
M: Metabolism
G: Growth

- **Nitrogen transformation**
  - Fodder remains, digestion products, dead organisms

$NH_3 + H_2O = NH_4^+ + OH^-$

< pH 7 >

$NH_3$ = ammonia – fish poisoning (optimum: < 0,01 mg/l)

$NH_4^+$ = ammonium – not fish poisoning (partial plant available)

  - Nitrification

$2\ NH_4^+ + 3\ O_2 = 2\ NO_2 + 2\ H_2O$

$2\ NO_2 + O_2 = 2\ NO_3$

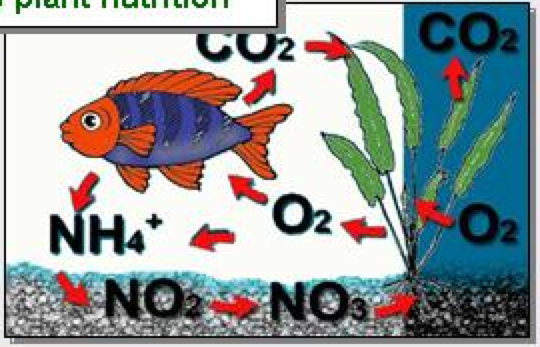
$NO_2$ = nitrite – fish poisoning (optimum: < 1,0 mg/l)

$NO_3$ = nitrate – not fish poisoning

(optimum: < 200 mg/l) plant nutrition

  - Denitrification

$2\ NO_3 + 3\ C = 3\ CO_2 + N_2$



## aquaculture

- beginning: stocking of fenced in waters with fish, natural fodder
- Additional feeding (cereal)
- combination with animal breeding (excrements as nutrition source)
- today : highly developed feed material
- By aquaculture production of high-value protein food in large amounts

## Today environmental protection: Aquaponic

- Aquaponic = combination of fish and plant production within a closed water cycle
  - Plants take up nutrients which have been excreted by fish
  - Thereby securing high water qualities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- **Environmentally related diseases**
  - temperature:
    - Water temperature has impact on living processes, on other environmental factors as well on natural resilience of fish against stress and exposure to pathogens
    - Highly increased or lowered water temperatures or extreme temperature changes means high stress for fish and ma lead to diseases and death
  - Lack of oxygen:
    - Reaction of fish following oxygen deficiancy: respiratory dysfunction, observable disquiet, food refusal and death by suffocation
    - Lacking oxygen supply raises susceptibility of fish to diseases
  - Poisoning and other threats  through foreign substances:
    - Damage through heavy metals, insecticides or hormones
    - thereby constraining metabolism and reproduction


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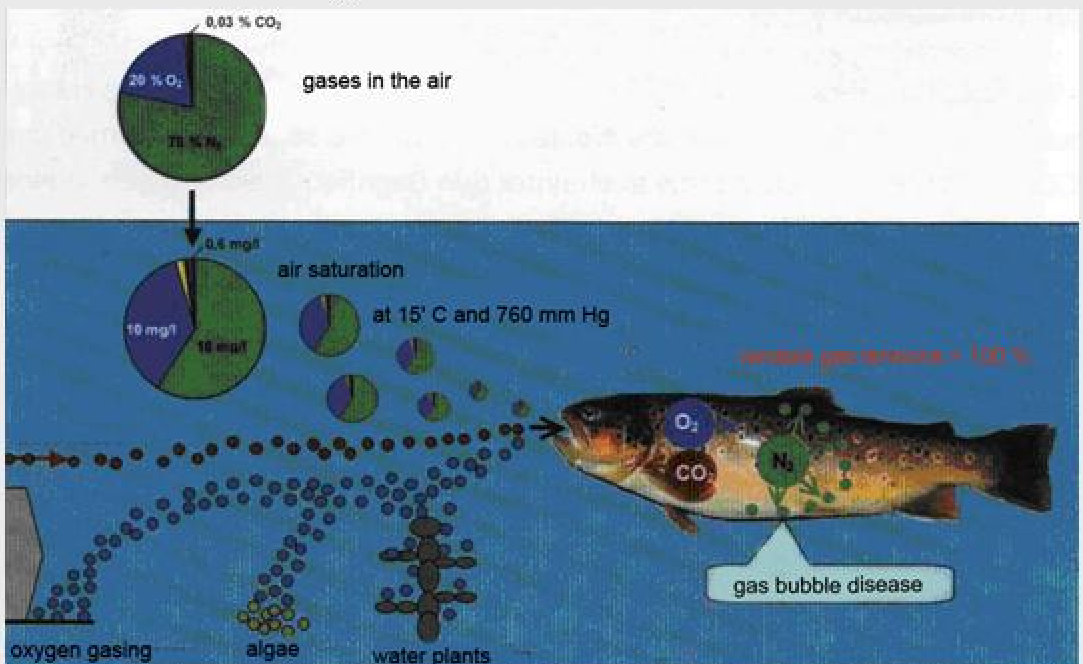
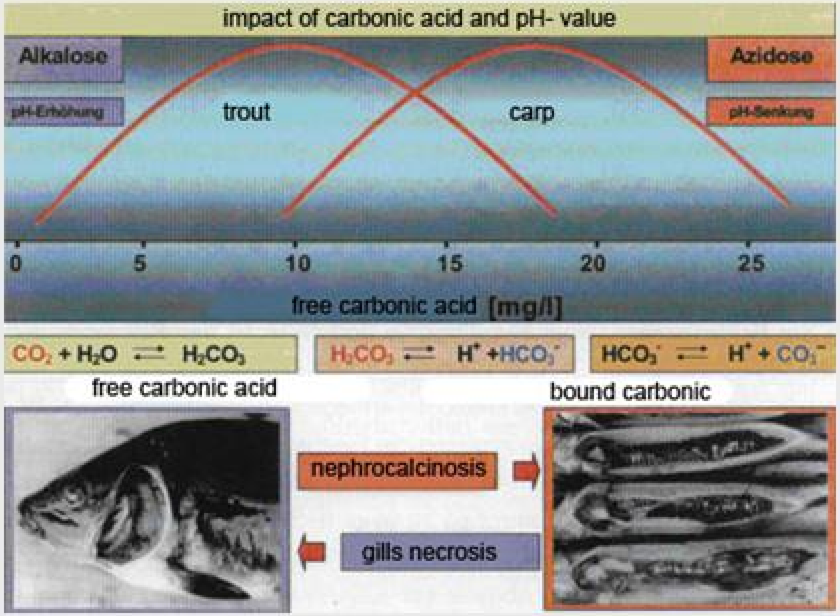
- **Environmentally related diseases**
  - pH-value:
    - Extrem deviation from neutral ph-values (pH 7) leads to serious damage, especially on gills
    - Acidity disease: from pH < 5 gray coating and browning of gills
    - Base disease: from pH > 9,5 strong mucus and burning of gills
  - Poisoning through nitrogen compounds
    - Especially through ammonia ($NH_3$) und salpeter ($HNO_2$)
    - rising $NH_3$-concentration in water leads to blockage of secretion through the gills → ammonia poisoning! → damage of gills!
    - High pH-values enforce poisoning further
    - high pH-values lead to rising $HNO_2$ content → disrupted oxygen transport in blood → breath shortage!
  - Poisoning and other threats through foreign substances :
    - Damage through heavy metals, insecticides or hormones
    - thereby constraining metabolism and reproduction

- **Environmentally related diseases**
  - Gas bubble disease:
    - Air enrichment in water (i.e. pumps) may lead to over accumulation of air in water (abide maximum injection depth of 1,5 m)
    - Over saturation of gas: to much gas, esp. nitrogen infiltrates into fish
    - Gas overtension → diving disease



- **Environmentally related diseases**
  - Impact of carbonic acid and ph-value :
    - Extrem deviation from neutral ph-values (pH 7) leads to serious damage, especially on gills
    - Acidity disease: from pH < 5 gray coating and browning of gills
    - Base disease: from pH > 9,5 strong mucus and burning of gills





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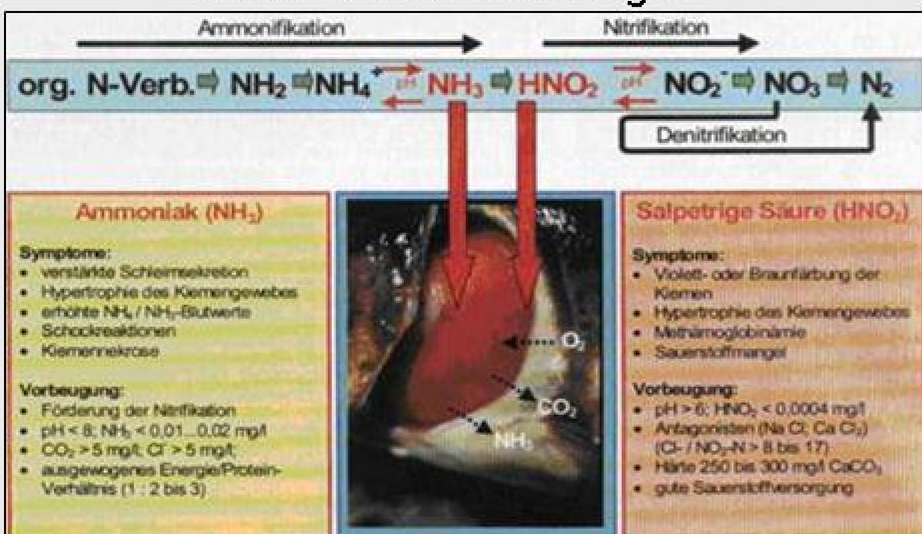


**Threshhold value:**

$NH_3$ = < 0,01 mg/l

$HNO_2$ = < 0,0002 mg/l



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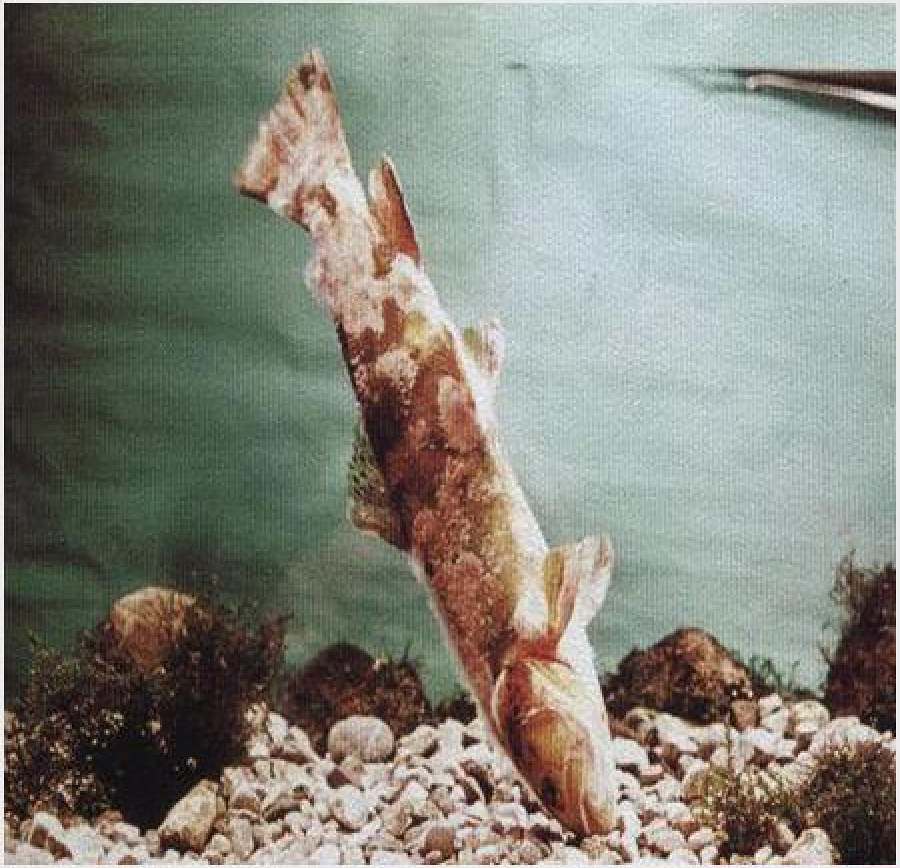
- Alteration of „seuchenbiologischen“ balance
- Contamination with organic substances



1. **Waste water treatment in constructed wetland**
2. **crop farming without substrates**
3. **Nutrious requirements of plants**
4. **Potential plant assortment**



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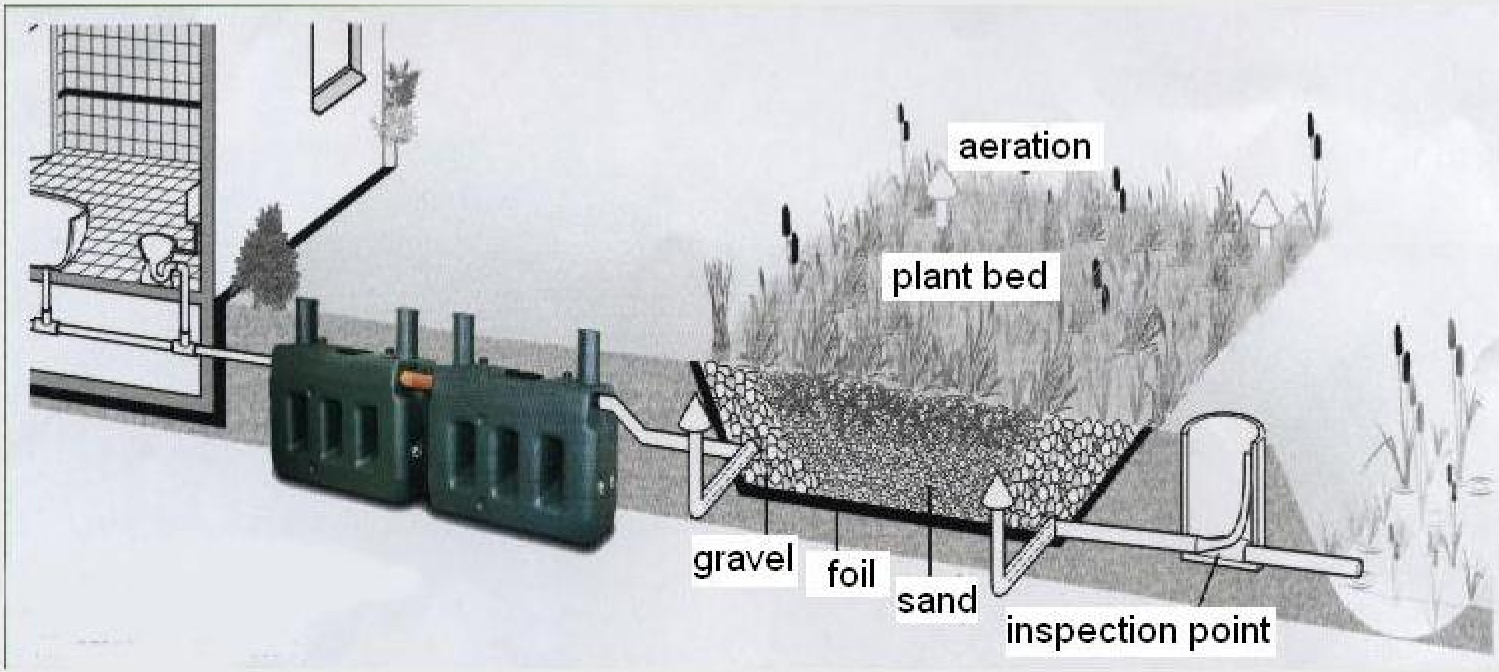
# 1. Wastewater treatment in constructed wetlands



# SUBSTRATES USED IN HYDROPONICS

- **anorganic substrates → serve only as footholding, but do not contribute to nutrient uptake**
  - foamed clay
  - perlite
  - vermiculite
  - coco substrate
  - granite chippings
  - volcanic slag
  - sand
  - rock wool





- **complete abandonment of substrates**
  - Roots of fixated plants float freely in circulating nutrient solution

# NUTRITIOUS REQUIREMENTS OF PLANTS

- Plant growth depends on light, temperature and water supply
- Roots supply water and nutrients for the plant
- To achieve a fertilizing effect, the nitrogen in the fish water needs to be accumulated to 50 mg/l

| Mineral compounds | Uptake by plant in form of | Adequate concentration (relating to dry substance) | |
|---|---|---|---|
| | | mg/kg | % |
| **Macro elements** | | | |
| nitrogen (N) | $NO_3^-$ / $NH_4^+$ | 15.000 | 1,5 |
| potassium (K) | $K^+$ | 10.000 | 1,0 |
| phosphor (P) | $H_2PO_4^-$ / $HPO_4^{2-}$ | 2.000 | 0,2 |
| Calcium (Ca) | $Ca^{2+}$ | 5.000 | 0,5 |
| magnesium (Mg) | $Mg^{2+}$ | 2.000 | 0.2 |
| sulfur (S) | $SO_4^{2-}$ | 1.000 | 0,1 |
| oxygen (O) | $O_2$ / $H_2O$ / $CO_2$ | 450.000 | 45 |
| carbon (C) | $CO_2$ | 450.000 | 45 |
| hydrogen (H) | $H_2O$ | 60.000 | 6 |
| **Micro elements (selected)** | | | |
| chlorine (Cl) | $Cl^-$ | 100 | 0,01 |
| iron (Fe) | $Fe^{3+}$ / $Fe^{2+}$ | 100 | 0,01 |
| manganese (Mn) | $Mn^{2+}$ | 50 | 0,005 |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# POTENTIAL PLANT ASSORTMENT



ผักคาวตอง
(Houttuynia Cordata Thumb)

ผักแผว
Globe Amaranth

ผักแขยง
Finger grass

ผักกาดหอม
Lactuca sativa

B. r. chinensis

Rosen

Lilien


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# Functioning of demonstration site

1. **pond (aquaculture): volume, fish stock, fodder input, discharge of N and P per kg**

- **Volume**
  - 2 fish ponds comprising total 10 m³
  - Sealing by plastic foil
  - aeration enclosure

- **Fish stock and fodder input**
  - Stock of approx. 6.000 red tilapia fingerlings
  - 1 kg increase / kg fodder
  - approx. 20 % loss


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## 2. plants (Hydroponic): substrate, plant assortment, plots

- **Substrates**
  - Coarse grained lava granulates

- **Plant assortment**
  - rice
  - salads, vegetables, herbs
- **plots**
  - 2 hydroponic plots
  - border of natural stone walls and bottom coating of PVC foil

## 3. Water cycle as connecting element



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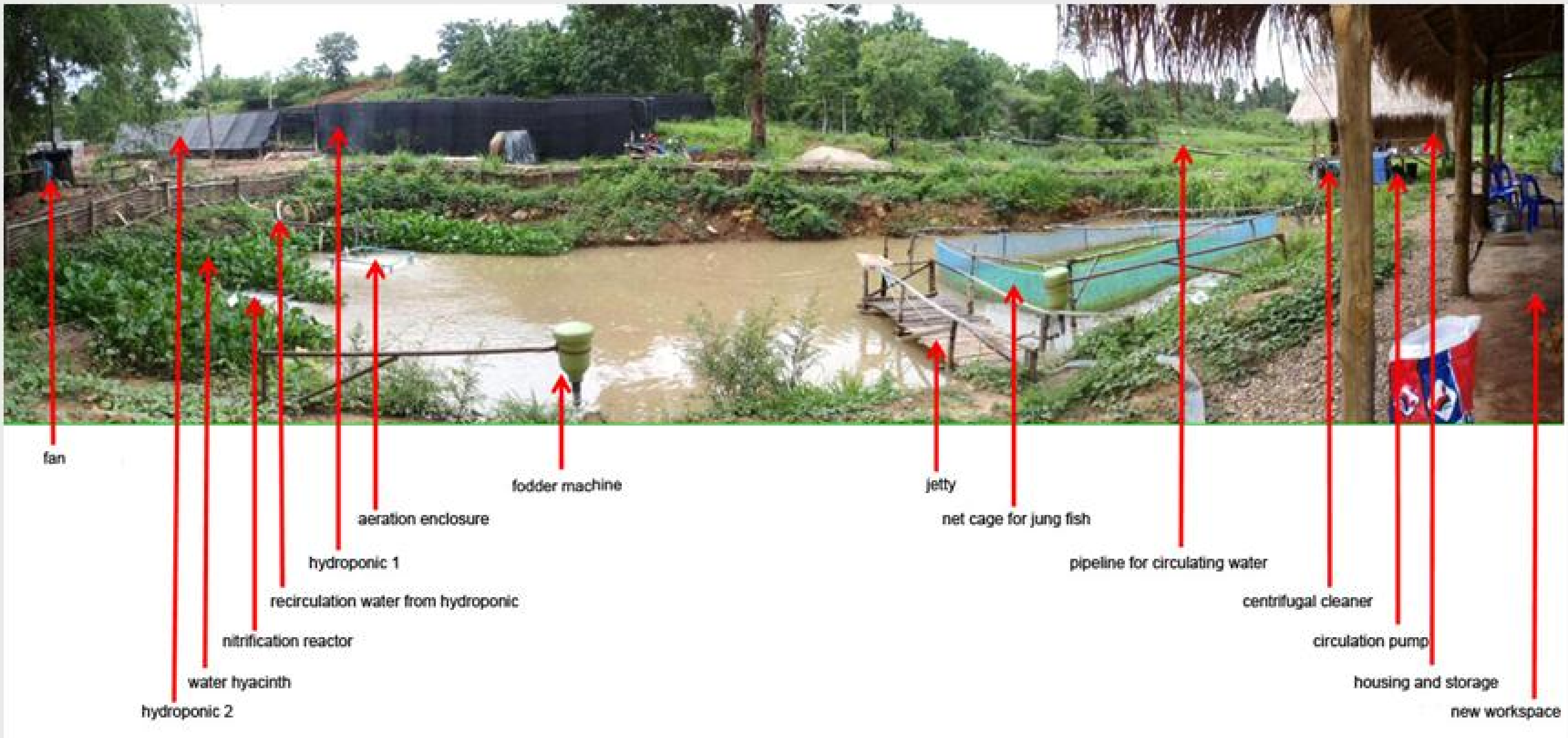
## overview


fan
fodder machine
jetty
aeration enclosure
net cage for jung fish
hydroponic 1
pipeline for circulating water
recirculation water from hydroponic
centrifugal cleaner
nitrification reactor
circulation pump
water hyacinth
housing and storage
hydroponic 2
new workspace

# PRACTICAL APPLIANCE

- **Measurement of:**
- **oxygen**
- **pH-value**
- **nitrogen**
- **Visible depht**
- **Test weighing**

- **fodder and fodder machine, fodder application and quality**
- **Aeration equipment**


Thank you for your attention!
PRO Arkades