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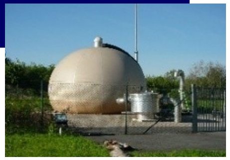

# Fermenter design
# 发酵装置设计与选择

W. Bidlingmaier

Lesson to learn:

学□ 内容□:

- Chategories of reactors are common in AD

  普通□ 氧□ 酵厂中的□ 酵罐□ 型

- The different parameters which influence the processing

  影响反□ □ 程的各□ 因素

- Design of a dry reactor

  干□ 酵□ □

- What factors con hint the process

  哪些因素暗示反□ □ 程□ 程

# Fermenter- and process parmeters
# 发酵罐和处理方法的参数

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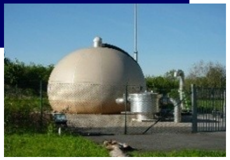

**Hydraulic dwelling time**

**停留时间：**

The dwelling time of the substrate in the fermenter 物质在发酵罐中的停留时间

Dwelling time[d] = working volume of the fermenter [m3] /substrate volume introduced daily [m3d-1] 停留时间 = 发酵罐体积 / 每天输入物质的体积

$$Verweilzeit\ [d] = \frac{Arbeitsvolumen\ des\ Fermenters\ [m^3]}{T\ddot{a}glich\ zugef\ddot{u}hrtes\ Substratvolumen\ [m^3 d^{-1}]}$$

**The recommendation for mesophile operation is 30 days.**
**中温运行下建议停留 30 天**

# Example: Dwelling time
# 举例：停留时间



- **Usable fermenter volume 1200 m³**

  发酵罐有效使用体积为 1200m³

- **If 40 m³ is added daily, the dwelling time will be as follows:**

  每天输入 **40m³**， 那么停留时间为：

- **Dwelling time = 1200 m³ / 40m³*d⁻¹ = 30 days**

# Organic dry matter 有机干物质

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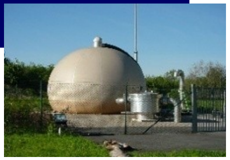

Cofermentate comprises of: 可发酵物质是指：

- organic substance 有机物质
- inorganisc substance (annealing residue) 非有机物（燃烧剩余物）
- water 水分

e.g. Maize silage: 例如 玉米青储饲料

- 65 % water 65% 的水
- 35 % dry matter 35% 的干物制
- 5 % annealing residue 5% 燃烧剩余物（灰分）
- ( = 85.7% of the dry matter) （总固体为 85.7% ）

Organic dry matter (odm) in 1kg of silage 1kg 青储饲料中有机干物质

1000g FM （湿重）； 650g water （水）； 350g dry matter （总固）– 50g ann.res. ( 灰分） = 300 g odm （有机干物质） or 350 * 85,7/100 = 300g odm

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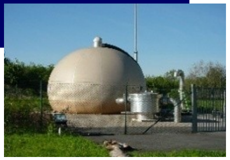

# Fermenter- and process paramaters
# 发酵罐和处理参数

## Load in the digester chamber

发酵罐负载量： ：

an important factor for estimating the possible conversion in fermenter. 最重要评价发酵罐内发酵体积大小的参数

$$\frac{(kg\ oTS)}{m^3 d} = \frac{org.\ Trockensubstanz\ pro\ Tag\ [kg\ oTS d^{-1}]}{nutzbares\ Gärbehältervolumen\ [m^3]}$$

有机物输入量 = 每天有机干物质质量 / 实际发酵罐体积

(kg odm = org. dry matter per day […..]/usable fermenting tank volume

# Fermenter and process parameters
# 发酵罐和处理参数

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## Sludge load : 污泥承载量:

**In order to estimate the accurate loads,**
**Odm determination in fermenter possible.**

**必要的准确评价承载量，以及发酵罐中有机物含量的方法**

Sludge load [..] = dry matter introduced per day […]/org. dry matter in fermenter

$$Schlammbelastung\ \frac{[kg\ oTS]}{[kg\ oTSd]} = \frac{zugef\ddot{u}hrte\ org.\ Trockensubstanz\ pro\ Tag\ [kg\ oTSd^{-1}]}{org.\ Trockensubstanz\ im\ Fermenter\ [kg\ oTS]}$$

污泥承载量 = 每天输入的有机干物质量 / 发酵罐中总有机干物质量

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# Hydraulic dwelling time 水利停留时间

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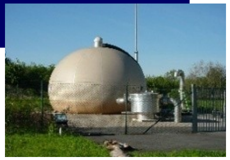

**Dwelling time – <10 up to over 100 days possible**

停留时间在小于 **10** 天或者多余 **100** 天是可能的

- **Gas output increases to a maximum** 产气一直到最大量
- **The lesser the poorer is the gas output** 气体量越少，产气越不好
- **practice 25-100 days** 实践中一般在 **25-100** 天
- **Under 20 days decreasing gas output, odour problems**
  **20** 天以内气体产量，臭气问题降低

**cofermentate higher dry matter** 可发酵的干物质含量高

- **Longer dwelling time possible** 可能较长的停留时间
- **Discharging volume low** 气体产量不足
- **Increasing load of digester chamber to be observed**
  注意有机物承载量增加问题

**cofermentate lesser dry matter** 可发酵的干物质含量低

- **high exchange volume** 较高的交换体积
- **Dilution of biogenous stock** 生物质的稀释
- **Quick fermentation: observe acid enrichment**
  快速降解：注意酸的累积问题

# Digester chamber load 有机物承载量

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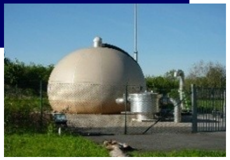

- In mesophile operation: 中温条件下

  range about 0.5 – 10 *[kg odm/(d *$m^3$) ]* 范围
- Gas output sinks with increasing load

  In the range 1- 3 [kg *odm/(d *$m^3$) ]* a linear decrease of about 10% on

  气体产量随承载量的提高而降低，一般在 1-3 [kg *oTS/(d *$m^3$) ]*，产气量直线降低率为 10%。
- Increasing the load to about 1 [kg *odm/(d *$m^3$ )]*

  Commonly: addition of 2 to 3 [kg odm/(d *$m^3$)]

  on addition of cofermentate, the value should stay below 5 [kg *odm/(d*$m^3$)]*

  Mono fermentation up to 10 [kg *odm/(d*$m^3$)]*

  提高承载量 1[kg *oTS/(d *$m^3$ )]*

  通常：输入 2 bis 3 [kg oTS/(d *$m^3$)]

  如果以总输入物质为单位， 那么这个输入量应该在 5 [kg *oTS/(d*$m^3$)]* 以下， 单物质发酵在 10 [kg *oTS/(d*$m^3$)]* 以下

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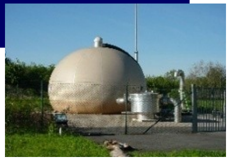

# Dwelling time and load of digester chamber
# 停留时间和有机物承载量

- Substrate parameter such as type, value, quantity, concentration, degradation speed to be observed
  物质参数，如种类， 数量，浓度， 可降解度
- Substrate dwelling time max. load:
  物质的停留时间以及最大的承载量：
  - liquid manure (cow)+ NawaRo ≥ 50d; 3-4 [kg/m^3*d].
    牛粪和可再生物质
  - liquid manure (pig) + NawaRo ≥ 80d; 3-4 [kg/m^3*d].
    猪粪和可再生物质
  - NawaRo mono fermentation ≥ 80d; bis 3 [kg/m^3*d].
    单独的可再生发酵物

# Add-on frequency 底物输入频率

- In practice about 24 portions / day 实践经验一天 24 份
- with add-on frequency not adjusted to the substrate
  - decreasing gas out put

    如果底物输入频率达不到，那么生物气产量就会降低
- persistant substrates 3-11 Port/day

  难降解物质 3-11 份 / 天
- readily degradable substrates up to 24 Port/day

  易降解物质 可达 24 份 / 天
- the higher the reactor load and the shorter the dwelling time, the higher the add-on frequency

  反应罐输入量越大， 以及停留时间越短， 那么频率就越高

# Fermenter and process paramaters
# 发酵罐和处理参数

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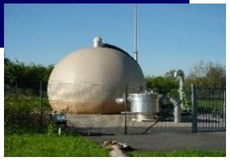

## Biogas formation rates：生物气产气率：

Gas quantity generated per time unit *[$l_N$/d ]*. *单位时间内的产气量*

## Gas pipe：产气效率：

Gas volume generated per day is related to the fermenter volume 产气体积除以发酵罐体

$$\frac{m^3}{m^3\,d} = \frac{erzeugtes\ Gasvolumen\ pro\ Tag\ [m^3 d^{-1}]}{Fermentergröße\ \ [m^3]}$$

m3/m3d=gas volume generated per day [….]/capacity of fermenter[m3]

| | | | |
|---|---|---|---|
| **Gas output** | **e.g. *m³/ kg odm*** i.e. **m³/ t wm** | | with respect to the substrate or ***m³/ GV*** |
| **el. energy** | ***kWh/t FM*** | | |

# Methane output, normal conditions
# 甲烷气产量，标准条件

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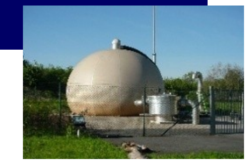

- **Only the total volume of gas can be measured.**

  **仅仅可以测量总气体体积的大小**

- **quantity of methane from volume and content % determine**

  **甲烷气产量可以通过总体积和百分含量来确定**

  – **$m^3$ Methane = $m^3$ Biogas * % Methane /100**

  甲烷气体积 = 生物气体积 * 甲烷气含量

- **results given in $m^3$ under normal conditions (NB = 1013 hPa, 273 K)**

  **标况下的体积（大气压为 1013 hPa， 273 K)**

  –E.g.: 举例： Volume 体积 : 1000$m^3$ Gas

  Temperature 温度 : 25°C = 298 K

  air pressure 气压 : 998 hPa

  Volume under nc 标况下体积 = 902,5 $m^3$

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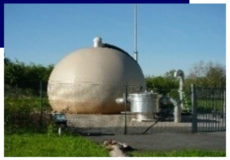


# Biogas output potential 生物气产气潜力

**Approximate calc.- example according to Buswell.**
**元素方程式 – 例如根据 Buswell 方程式**

- **Knowledge on the material composition of the substrate necessary.** 认识必要的物质原料组成成分

- **The gas output depends considerably on the material groups carbohydrates, fats and proteins with av. mol fractions of the element CHO.**
  气体产量主要和碳氢化合物，脂肪， 蛋白质，主要是碳氢氧元素有关

$$C_x\,H_y\,O_z \rightarrow (\frac{x}{2}+\frac{y}{8}-\frac{z}{4})$$

# Biogas output potential according to Buswell
# 生物气产量潜力 Buswell

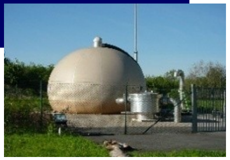
| Molanteil | Kohlenhydrat | Fett | Protein | Gesamtpflanze |
|---|---|---|---|---|
| | | | | |
| Kohlenstoff | 6 | 16 | 6 | 38 |
| Wasserstoff | 12 | 32 | 10 | 60 |
| Sauerstoff | 6 | 2 | 2 | 26 |
| | | | | |
| Rel. Atommassen C=12, H=1, O=16 | | | | |
| Molare Masse | 180 | 256 | 142,5 | 930 |
| | | | | |
| Methanertag in Mol (nach Buswell) | 3,0 | 11,5 | 3,8 | 19,7 |

Aus: FH Bochum, Solarnetz .

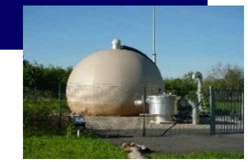
Molanteil=Mol fraction
Kohlenstoff=carbon
Wasserstoff=hydrogen
Sauerstoff=oxygen
Rel.Atommassen=rel. atomic mass
Molare masse= molar mass

Methane output in mol (according to Buswell)

Carbohydrate, Fat, Protein, Total plants



# Types and selection criteria for fermentersystems in biogasplants (2)
# 沼气厂发酵系统的型号和选择标准 (2)



# Anaerobic process

$$C_nH_aO_bN_cS_d + (4n - a - 2b + 3c + 2d)\ H_2O \rightarrow$$

$$1/8(4n + a - 2b - 3c - 2d)\ CH_4$$

$$+ 1/8(4n - a + 2b + 3c + 2d) CO_2$$

$$+ cNH_3$$

$$+ dH_2S$$

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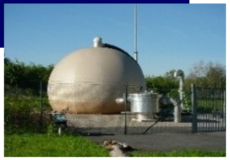
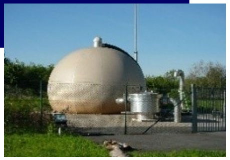


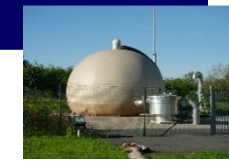
# The anaerobic process- biogas

| | 1. step | 2. step | 3. step | 4. step |
|---|---|---|---|---|
| name of step | hydrolysis | acidification | acetatification | methane production |
| start-product | complex sugar, protein, fat | simple sugar | amino acid, organic acids | acetat |
| micro-organisms | | acidogene micro-organisms | acetogene micro-organisms | methanogene micro-organisms |
| by-product | simple sugar | amino acid, organic acids | acetat | |
| end-product | $CO_2$ | $CO_2$, $H_2$ | $CO_2$, $NH_4$, $H_2$ , | $CO_2$, $CH_4$ |



# The anaerobic process
# 厌氧过程

| substrate 物质 | methane [Vol.-%] | carbon-dioxid [Vol.-%] | ammonia [Vol.-%] | hydrogene sulfide [Vol.-%] |
|---|---|---|---|---|
| sugar (glucose) 糖（葡萄糖） | 50 | 50 | - | - |
| fat 脂肪 | 71 - 75 | 29 | - | - |
| proteine 蛋白质 (average)（平均） | 38 -50 | 38 | 18 | 6 |



# The anaerobic process
# 厌氧过程

Methane 35 - 55 Vol.-%

Carbon dioxide 44 Vol.-%

3,5 - 5,5 kWh/m³ biogas

# The anaerobic digestion
# 厌氧发酵

| thermophilic | mesophilic |
| --- | --- |
| 50 - 55°C 高温 | 30 - 35°C 中温 |

-stability of process, microorganisms, gas production

过程稳定，微生物，气体产生

| wet 湿发酵 | dry 干发酵 |
| --- | --- |
| 10 mass% dry subst. | 35 mass% dry subst. |

-stability of process, inhibition 过程稳定，抑制

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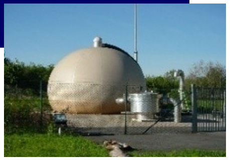

# The anaerobic digestion
# 厌氧发酵

single stage 一级

two stage 二级

| single stage | two stage |
|---|---|
| benefit: 优点<br>- low costs of invest<br>- simple control engineering<br>投资少，过程控制简单 | benefit: 优点 过程稳定，单独的溶液成分<br>- higher stability of the process<br>- individual solutions 高效，时间和体积<br>- higher efficiency reg. time and volume<br>- better sanitation( lower pH-in hydrolysis) |
| disadvantage: 缺点<br>- no optimisation possible 优化较难<br>- pH -problem (instability) pH 稳定问题<br>- general lower stability 一般稳定问题 | disadvantage:更好的清洁处理（水解 pH 低）<br>- higher costs of invest 投资高<br>- more difficult control engineering<br>工程控制难 |

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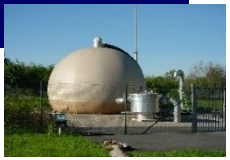


# The anaerobic digestion
# 厌氧发酵

| | | |
|---|---|---|
| temperature | [°C] | 30-35 und 50-55 |
| pH | [-] | 6,6-8 |
| water content | mass.-% w.b. | > 50 |
| redox potential | [mV] 氧化还原电势 | <-330 |
| alkalinity 碱度 | [mg $CaCO_3$/l] | >2000 |
| salt 盐 | [g/kg d.b.] | <20 |
| ammonium 氨 | [g/l] | <1-2,5 |
| hydrogene sulphide H2S | [mmmolar, Vol.-%] | <3, <1 |
| sulphide 硫 | [mg/l] | <100-400 |
| organic acids 有机酸 | [mg/l] | <15000 |

| Characteristics | Covered Lagoon | Complete Mix Digester | Plug Flow Digester | Fixed Film |
|---|---|---|---|---|
| **Digestion Vessel** | Deep Lagoon | Round/Square In/Above-Ground Tank | Rectangular In-Ground Tank | Above Ground Tank |
| **Level of Technology** | Low | Medium | Low | Medium |
| **Supplemental Heat** | No | Yes | Yes | No |
| **Total Solids** | 0.5 - 3% | 3 - 10% | 11 - 13% | 3% |
| **Solids Characteristics** | Fine | Coarse | Coarse | Very Fine |
| **HRT* (days)** | 40 - 60 | 15+ | 15+ | 2-3 |
| **Farm Type** | Dairy, Hog | Dairy, Hog | Dairy Only | Dairy, Hog |
| **Optimum Location** | Temperate and Warm Climates | All Climates | All Climates | Temperate and Warm |

* Hydraulic Retention Time (HRT) is the average number of days a volume of manure remains in the digester.

# Covered Lagoon Digester.
# 带盖的 Lagoon 发酵池

- Covered lagoons are used to treat and produce biogas from liquid manure with less than 3 percent solids.
  带盖的 lagoons 用于处理和生产沼气，一般原料为固体含量小于 3% 的液体肥粪。
- Generally, large lagoon volumes are required, preferably with depths greater than 3,6 m.
  一般大的 Lagoon 体积要求深度在 3.6 米以上。
- The typical volume of the required lagoon can be roughly estimated by multiplying the daily manure flush volume by 40 to 60 days.
  典型的 Lagoon 发酵池体积一般可以由每天投入的肥粪体积乘以 40 至 60 天（倍）。
- Covered lagoons for energy recovery are compatible with flush manure systems in warm climates. Covered lagoons may be used in cold climates for seasonal biogas recovery and odor control.
  这种带盖的 Lagoon 池一般在温和的气候下投入肥分是兼容的，当然也可以在较冷的气候下的个别季节性沼气回收和废气净化控制使用。

# Complete Mix Digester
# 完全混合池

- Complete mix digesters are engineered tanks, above or below ground, that treat slurry manure with a solids concentration in the range of 3 to 10 percent.

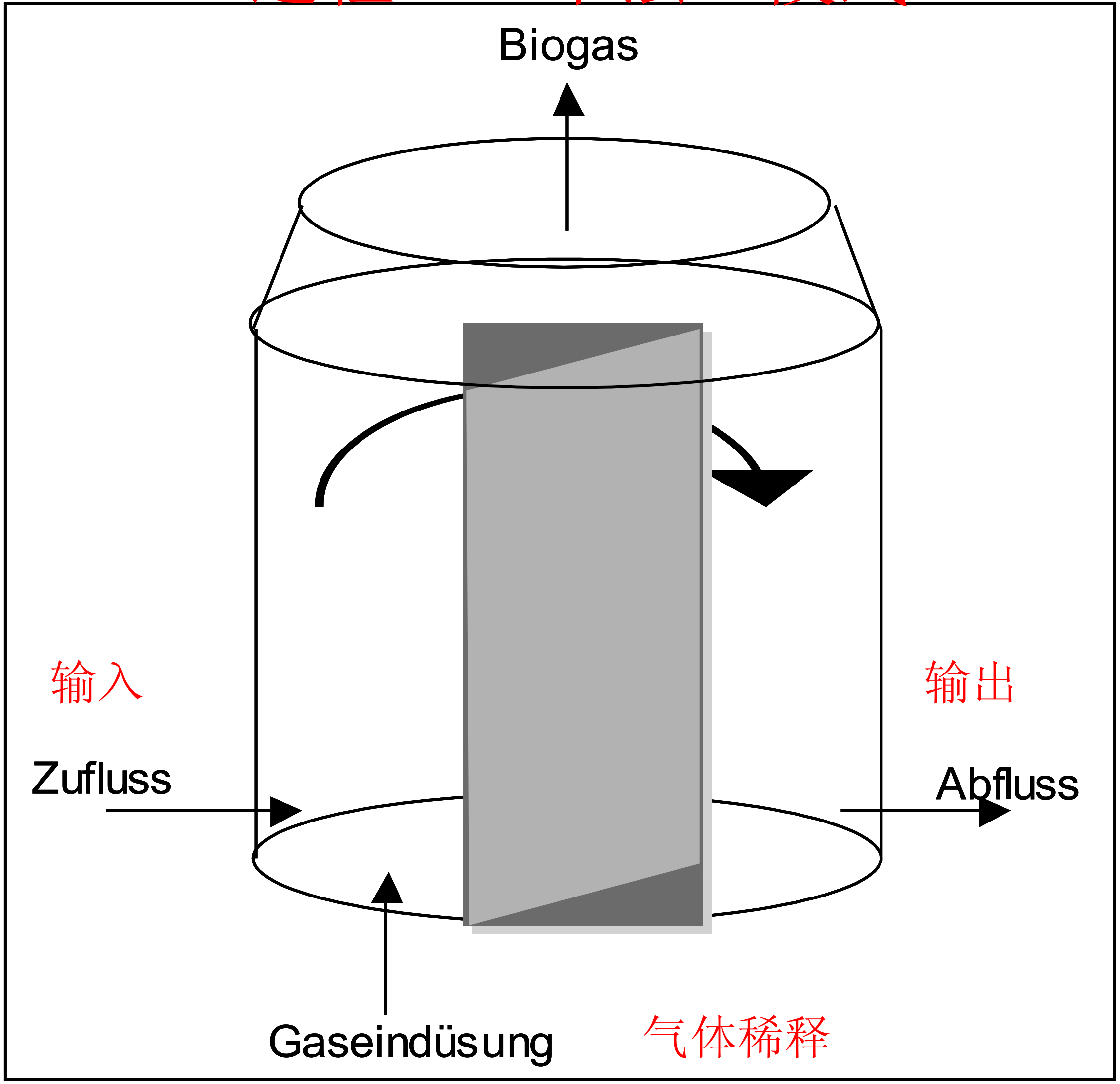
完全混合池是建在地上或者地下的发酵池，用于处理固体含量在 3-10% 的肥粪泥浆。

- These structures require less land than lagoons and are heated. Complete mix digesters are compatible with combinations of scraped and flushed manure

这种结构占地面积小（和 lagoons 池比较），并且是加热池，这种完全混合池能够兼容干或者冲刷肥粪。

# VALORGA-Process – dry single stage

VALORGA 过程 – 干法一段式



# Plug Flow Digester
# 活塞式流体发酵罐

- Plug flow digesters are engineered, heated, rectangular tanks that treat scraped *dairy* manure with a range of 11 to 13 percent total solids.
  活塞式流体发酵罐也是加热罐，长方形 ，一般处理固体含量在 11-13% 的干肥粪

- Swine manure cannot be treated with a plug flow digester due to its lack of fiber
  由于猪粪中纤维含量少，因而不适宜用于此装置

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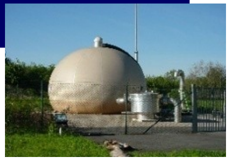
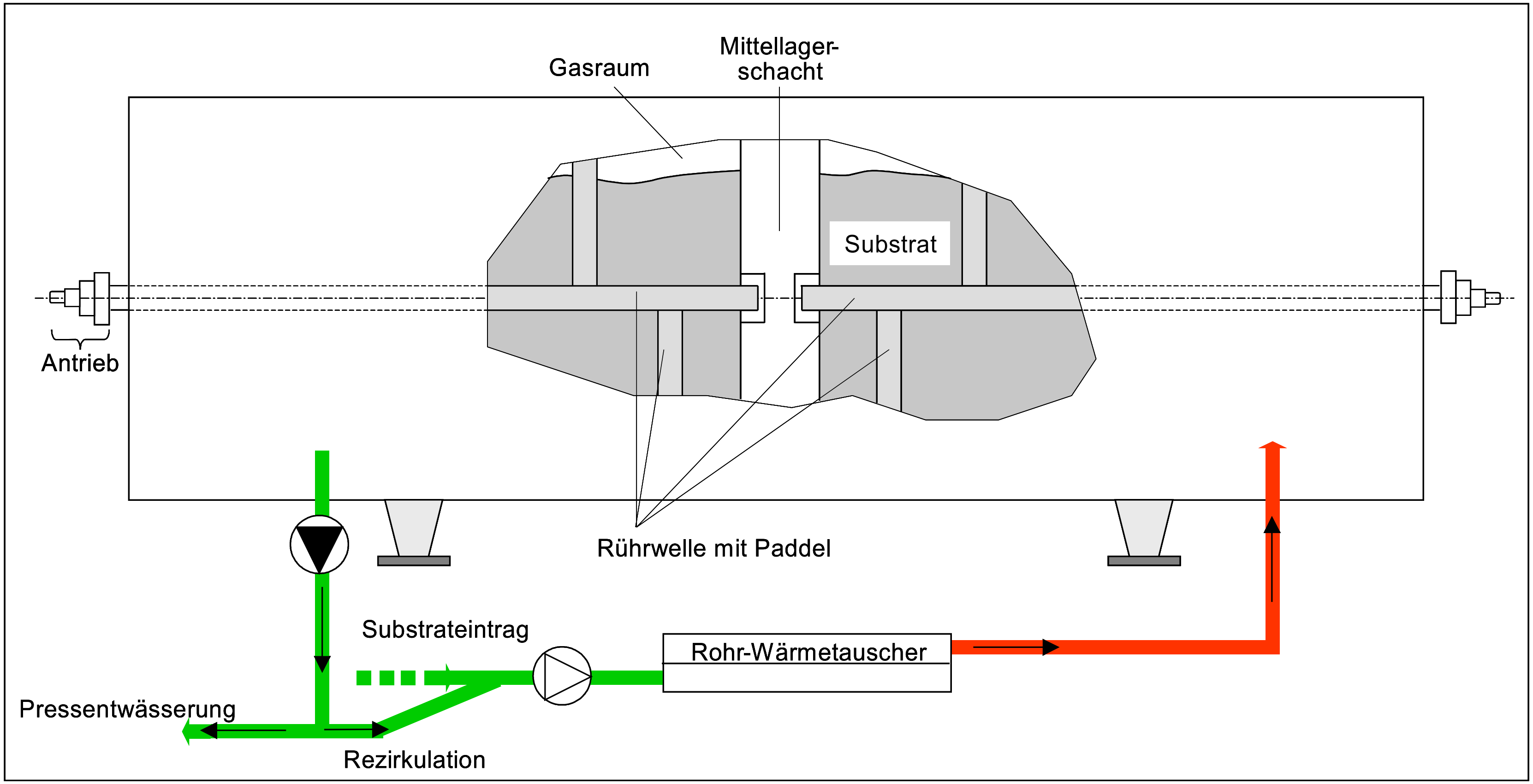


# KOMPOGAS-Process – dry, single stage

## VALORGA 过程 – 干法一段式

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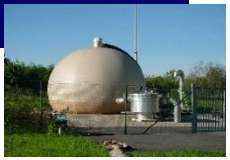
# Fixed Film Digester
# 固定膜发酵罐



Fixed-film digesters consist of a tank filled with plastic media. The media supports a thin layer of anaerobic bacteria called biofilm (hence the term "fixed-film").
固定膜发酵罐用塑料材质制成。这个媒介是一个供厌氧菌生长的薄膜，称为生物膜（因此也叫固定薄膜）

As the waste manure passes through the media, biogas is produced. Like covered lagoon digesters fixed-film digesters are best suited for dilute waste streams typically associated with flush manure handling or pit recharge manure collection.
当废物粪肥通过这个媒介，生物气就产生了。就像在 lagoon 发酵罐固定膜一样，此装置适合稀释的固体废物，最典型的就是冲刷肥粪液的处理，或者是肥粪收集坑内的物质。

Fixed-film digesters can be used for both dairy and swine wastes. However, separation of dairy manure is required to remove slowly degradable solids.
固定膜发酵池可以用于奶牛场和养猪厂的废物处理。然而，必须进行那些难降解物质的去除处理。

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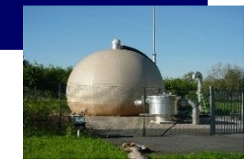
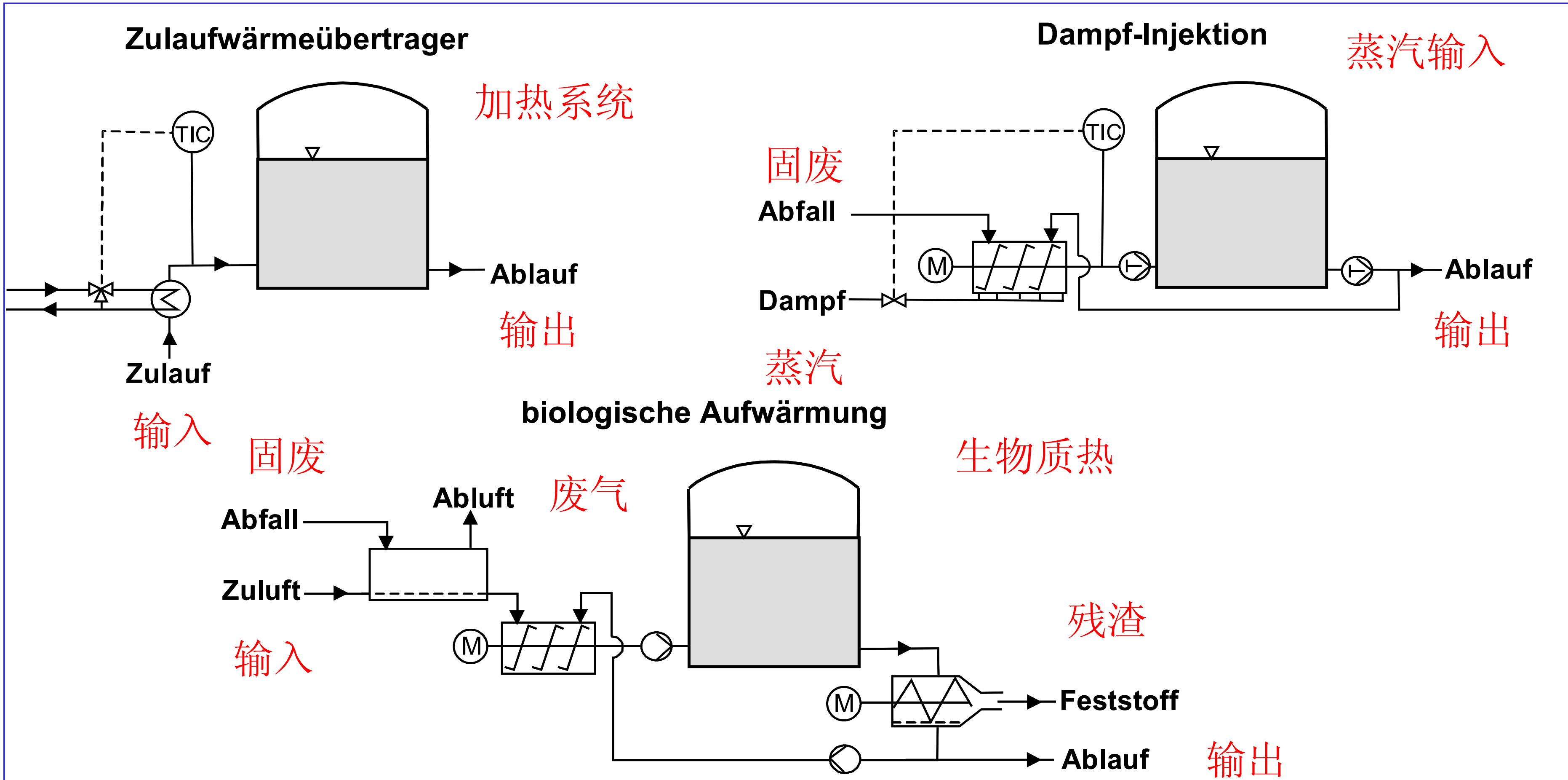


# Heating systems fo ractors
# 发酵罐的加热系统

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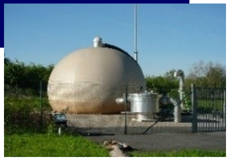
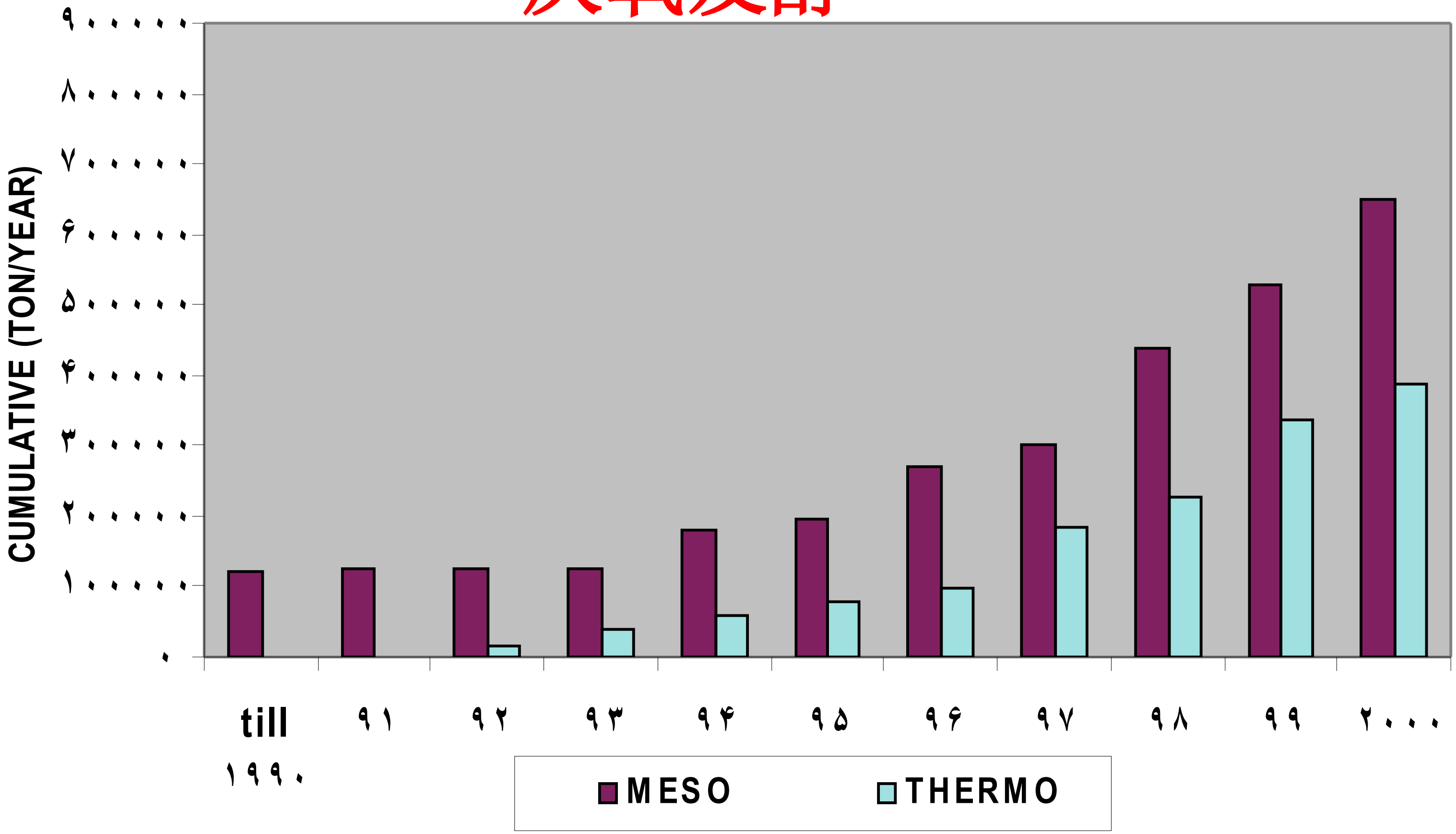
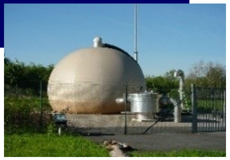


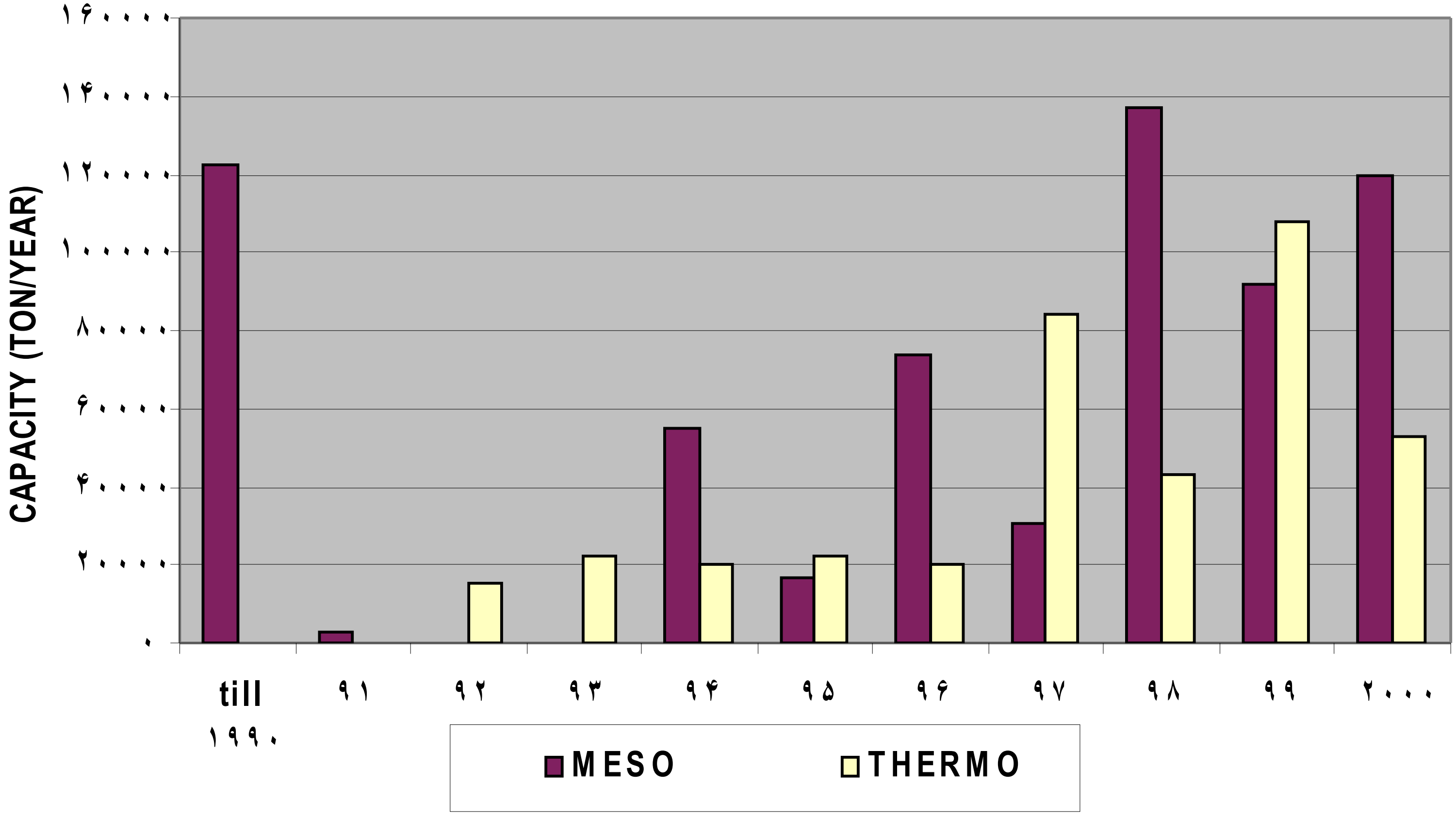
# The anaerobic digestion

# 厌氧发酵





# The anaerobic digestion
# 厌氧发酵



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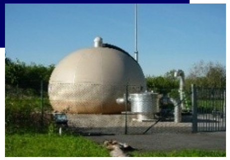
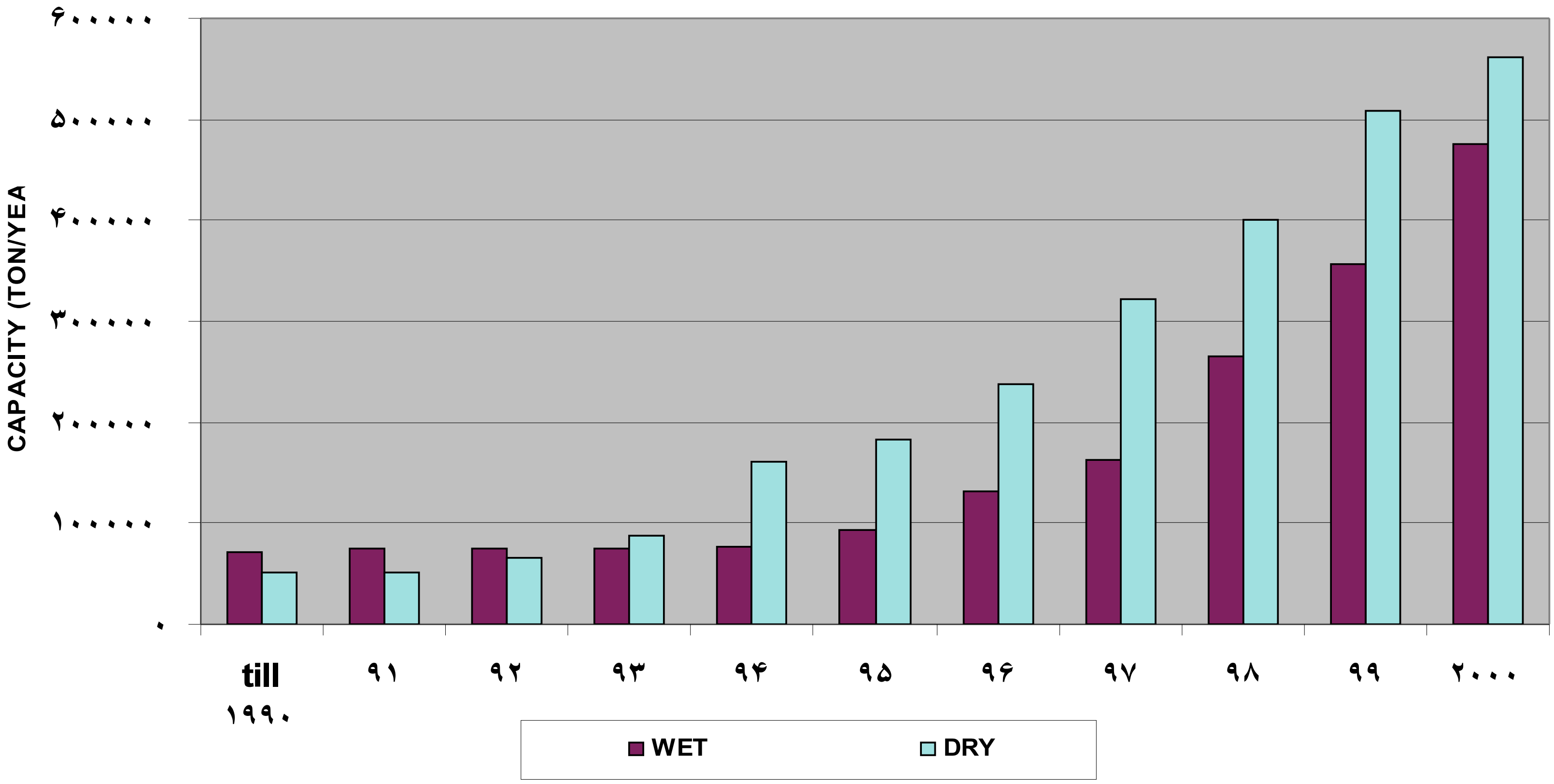


# The anaerobic digestion
# 厌氧发酵



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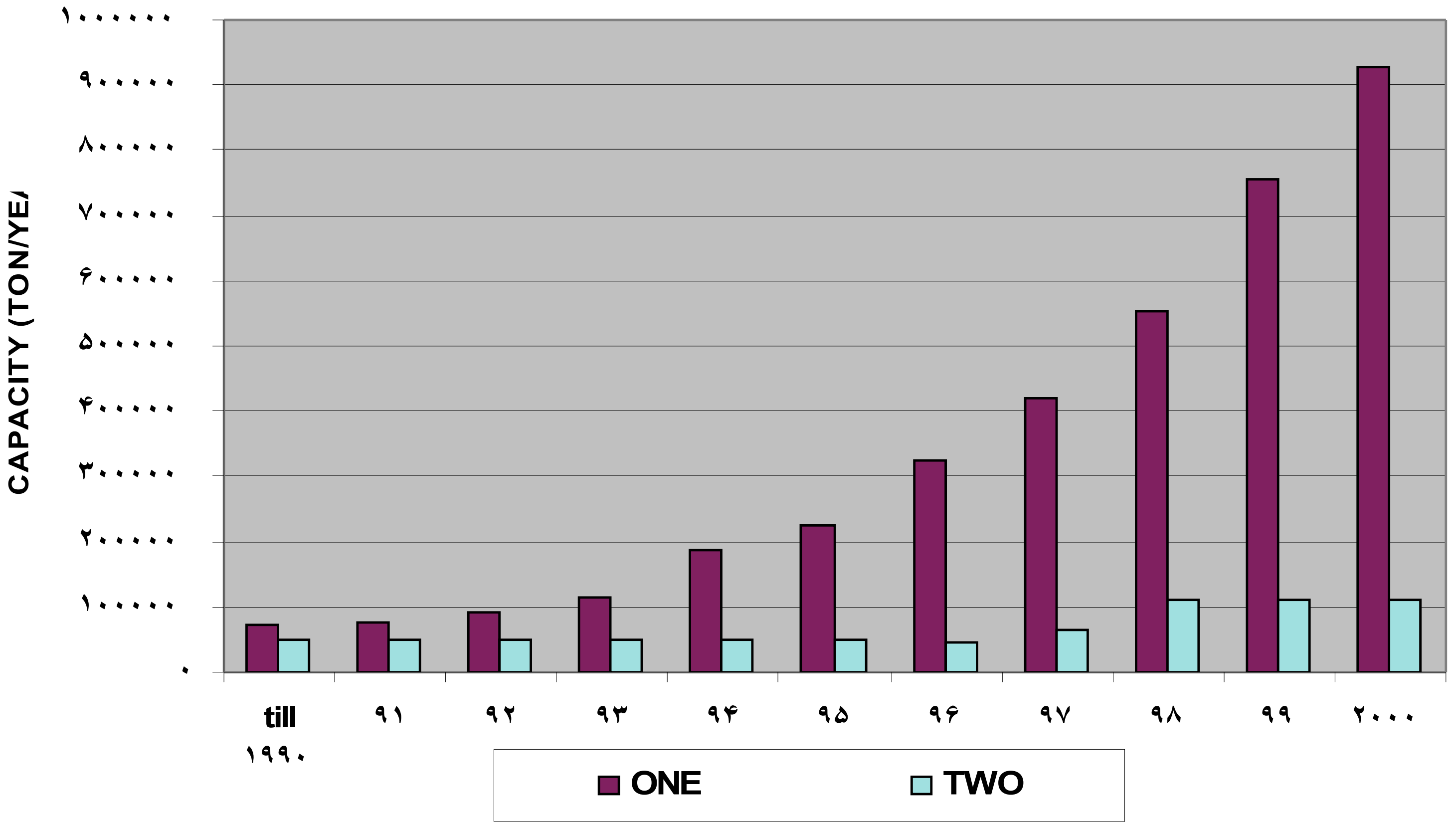
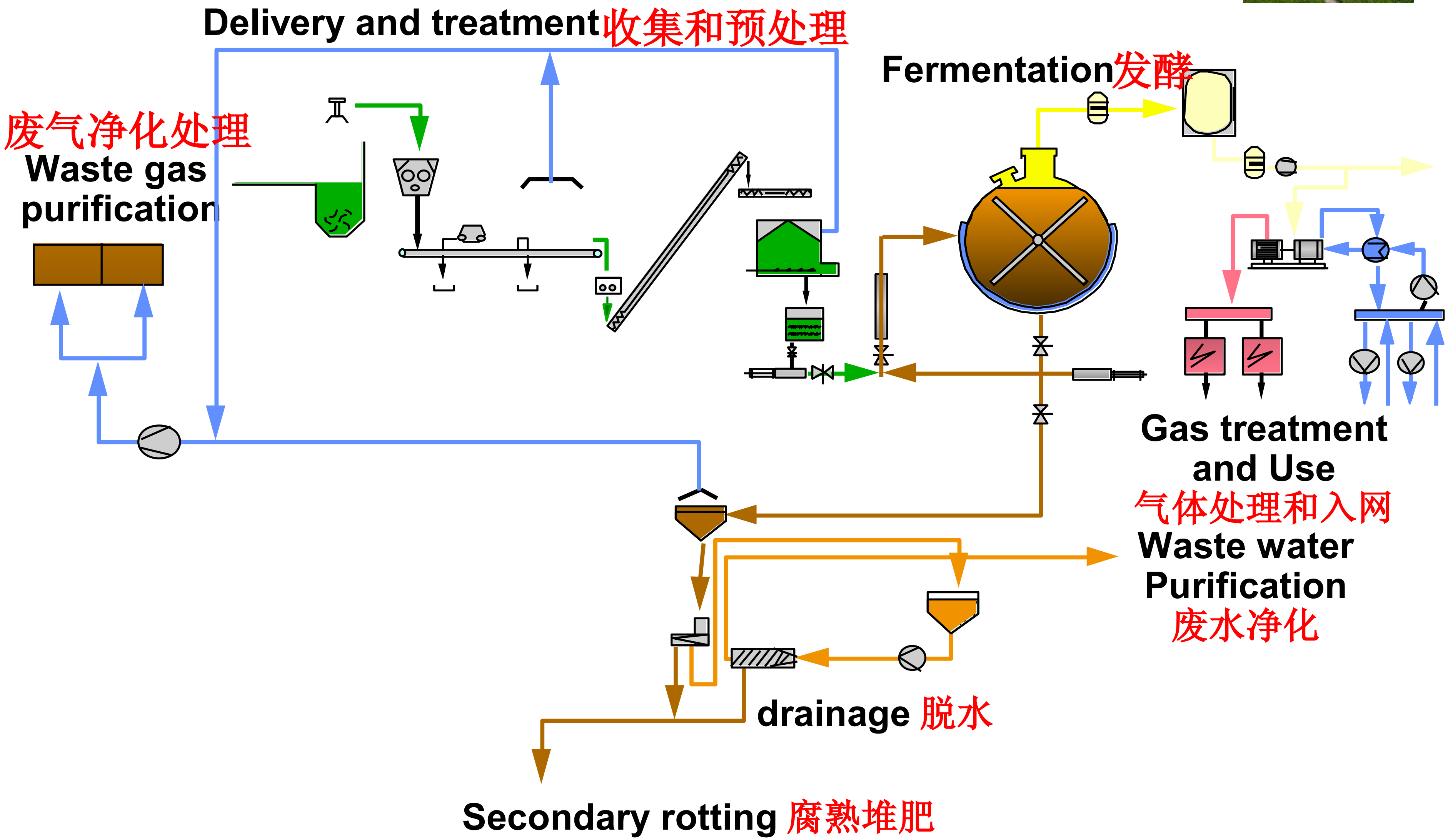
# The anaerobic digestion

# 厌氧发酵



Process flow chart fermentation plant

发酵厂流程图



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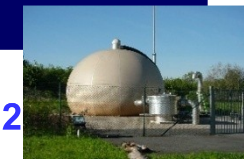

# Degradation steps for the formation of Methane & $CO_2$

甲烷气和 **CO2** 气体产生的降解过程

## 1. Degradation of carbohydrates according to Buswell:

根据 **Buswell** 碳水化合物的降解

$$C_nH_aO_b + \left(\frac{n-a}{4} + \frac{b}{2}\right)H_2O \rightarrow \left(\frac{n}{2} - \frac{a}{8} + \frac{b}{4}\right)CO_2 + \left(\frac{n}{2} + \frac{a}{8} - \frac{b}{4}\right)CH_4$$

**e.g. Glucose*** 例如葡萄糖 $C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$

## 2. Degradation of amino acids to acetic acid, Ammonia and carbondioxide

氨基酸降解为乙酸，氨和碳水化合物

$$CH_3CHNH_2COOH + 2CH_2NH_2COOH + 2H_2O \rightarrow 3CH_3COOH + 3NH_3 + CO_2$$

## 3. Degradation of fatty acids to acetic acid, hydrogen and carbondioxide:

脂肪酸降解为乙酸，氢和碳水化合物

**a) Butyric acid** 丁酸 $CH_3CH_2COO^- + 2H_2O \rightarrow 2CH_3COO^- + H^+$

**b) Propionic acid** 丙酸 $CH_3CH_2COO^- + 2H_2O \rightarrow CH_3COO^- + 3H_2 + CO_2$

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# Degradtion steps for the formation of Methane & $CO_2$

甲烷气和 **CO2** 气体产生的降解过程

**4. Carbondioxide - Reduction to Methane, Water and heat:**

碳水化合物降解为甲烷，水和热能

$$CO_2 + 4H_4 + H_2O$$ + heat

**5. Reduction of acetic acid to Methane and carbondioxide:**

乙酸降解为甲烷和碳水化合物

$$CH_3COOH \rightarrow CH_4 + CO_2$$

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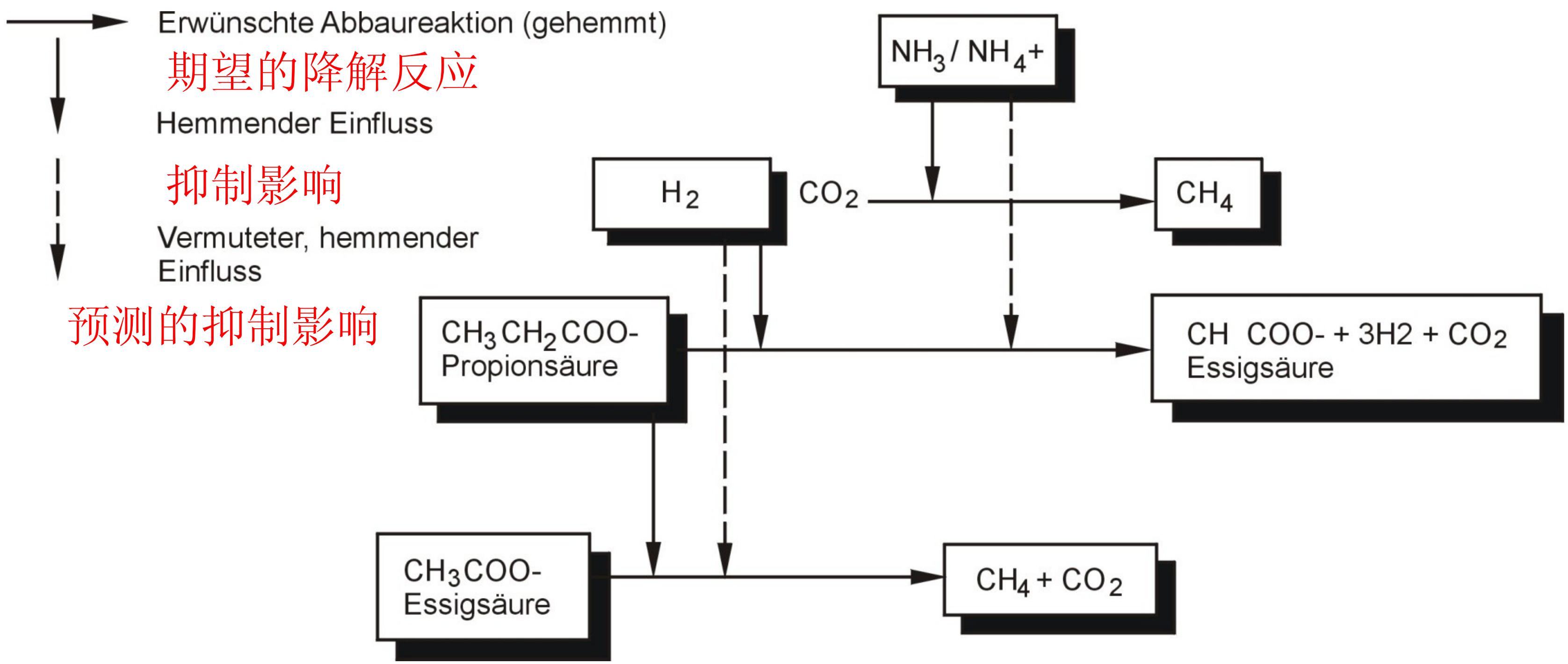
# Degradation reactions and inhibitory influences
# 降解反应以及抑制影响




- Adaption possible over many weeks
- Drop in pH - value only in the advanced state
- High concentration of propionic acid subsequent to ammonium inhibition

发酵时
开始阶
氨抑制
的增加

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# Parameters of process control
# 过程控制因子

**Good process conditions can be deduced from the following properties**

**如下特征为较好的过程控制条件：**

1.) Biogas quality: constant amplitude and average values of $CH_4$ content

生物气质量：恒定的波动并且大体在甲烷气的均值范围附近

2.) Biogas output: constant and within limiting values, according to the waste composition

生物气产量：恒定， 并且在范围极限值内， 根据固废组成成分

3.) Analysis values: satisfactory profile for organic acids, acid and $NH_4$ concentration within limiting values

分析值：满足有机酸的特征，以及酸， NH4 浓度在范围极限值内

4.) Temperatures: constant and close to optimum

温度：恒定，并且在优化温度附近

5.) Inoculation: suitable inoculation rate adjusted, according to $oTS_{ana}$ load

接种物：适宜的接种物，符合有机物负荷量

6.) pH-value: reaction later, especially if ammonium is high

pH 值：过后才会反应，特别是氨含量高时



Die Parameter sind entsprechend ihrer Priorität aufgelistet!

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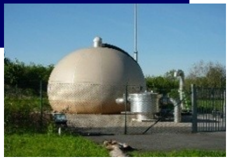
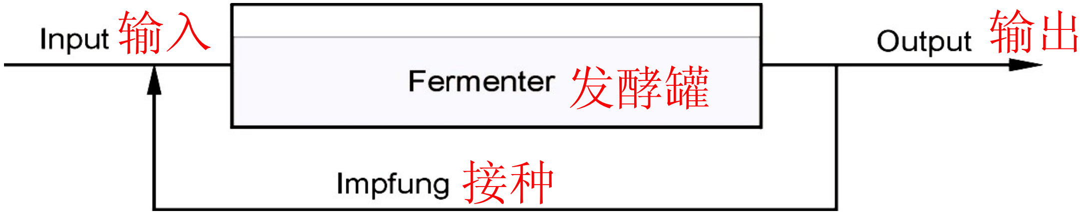


# Inoculation 接种物




Inoculation rate (number of inoculations / number of insertions): <u>0.25 < inoc. rate < 1</u>

接种比例（输入数）： 0,25 < 接种比例 < 1

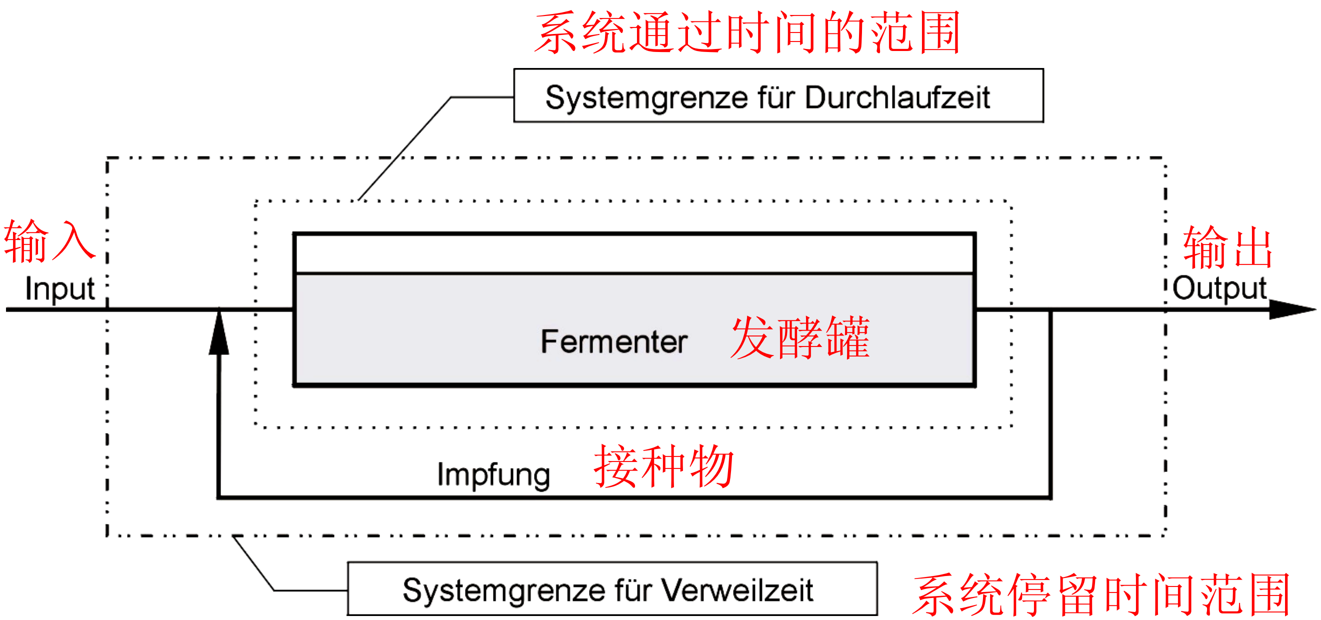
Press water - Recirculation also has an inoculation effect!

压缩水 － 循环也有接种的作用

Guidelines for inoculation: 接种的规定：

- Due to inoculation , it is important that the acids break down at the fermenter exit(especially Propionic acid), in order to avoid non-reduced acids being re-transported to the fermenter entry
  接种在发酵过程非常重要， 因为酸在发酵罐中被分解掉（特别是丙酸）， 为了避免，因此没被降解的酸将被重新回流到发酵装置中
- $oTS_{ana}$ high in waste, slightly higher inoculation rate in order to dilute the acid concentration at the entry
  垃圾中有机物含量高， 接种物也要增加，以此稀释发酵罐中的酸浓度
- no partial fermentation possible!
  不均匀发酵要避免！

# flow time and dwelling time
# 通过和停留时间




Flow time: 通过时间

m³ (Fermenter filling volume)
发酵罐填充体积）

m³ (Input + Inoculation) daily
每天输入和接种物量

Dwelling time: 停留时间

m³ (Fermenter filling vol.)
发酵罐填充体积

m³ (Input) daily 每天输入量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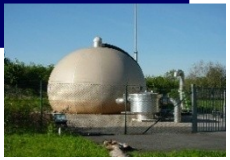


# Flow time and dwelling time)

通过和停留时间

17 days < dwelling time 停留时间 < 25 days
10 days < dwelling time 通过时间 < 15 days

**12 - 14 days should be attempted for flow time**

预计通过时间 12-14 天最佳

If possible not longer because:
最好不要时间过长，因为：

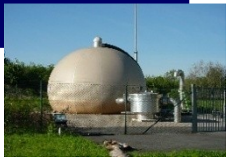
Substrate liquifaction and ammonium inhibition as consequence to the strong TS degradation takes place

较强的物质降解导致物质液化和氨抑制

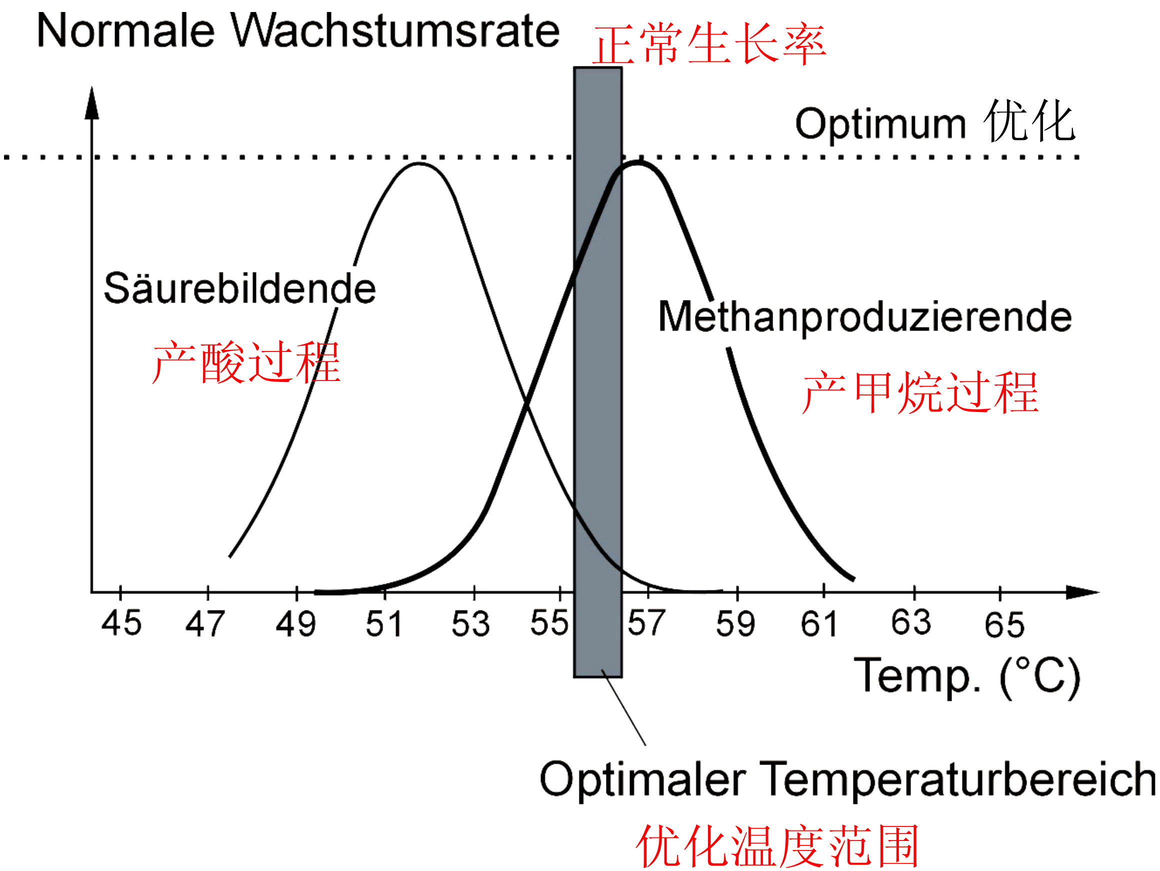
If possible not shorter because:

最好不要时间过短，因为：

the plug flow should be maintained,
disinfection should be guaranteed,
as well as enough time should be given for the degradation of organic acids.
物流应该保持一定时间，还要保持清洁，也要为有机酸的降解保持一段时间



# Influence of temperature on growth of bacteria
# 温度对菌种生长的影响




**Under ideal conditions:**

**优化条件下：**

Ammonium inhibition and other influences can lead to deviations,

optimum temperature depends on waste

Compostion

氨抑制和其他影响可能延缓反应，优化温度根据固废组成而不同

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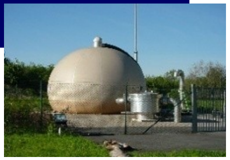


# Influence of temperature on ammonium inhibition

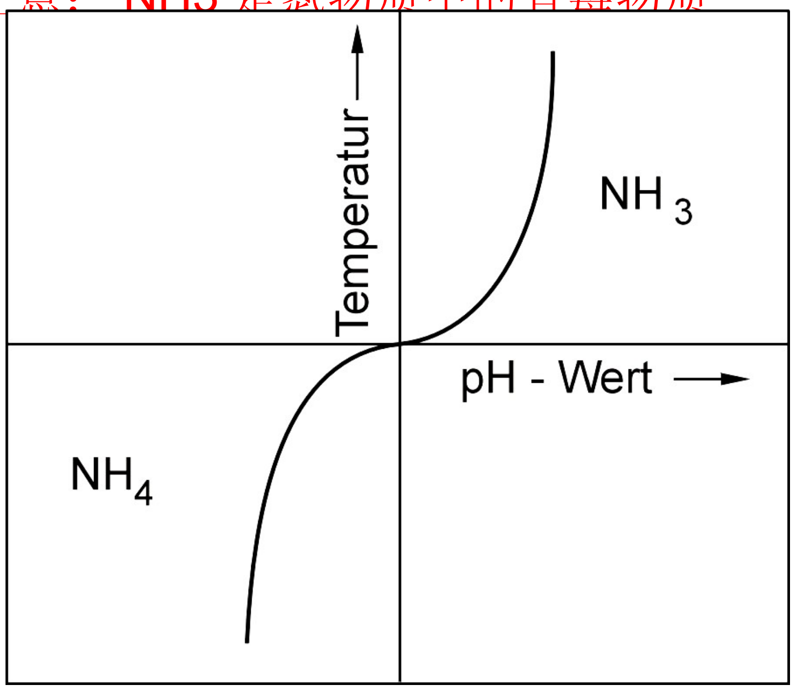
## 温度对氨抑制影响

The equilibrium between $NH_4$ and $NH_3$ adjusts according to to temperature and pH - value.

NH4 和 NH3 的重量相当，因而因温度和 pH 值不同而不同

Remarks: $NH_3$ is a toxic form of nitrogen

注意： NH3 是氮物质中的有毒物质




Increase in temperature leads to stronger inhibition of Ammonium!

温度的升高加强氨的抑制作用

Increase in pH – value leads to stronger inhibition of Ammonium!

pH 值的增加提高了氨的抑制作用

If both are increase, there will be a doubled tendency towards Ammonium inhibition!

如果两者都提高， 将使氨抑制作用提高 2 倍

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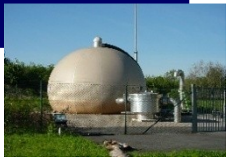
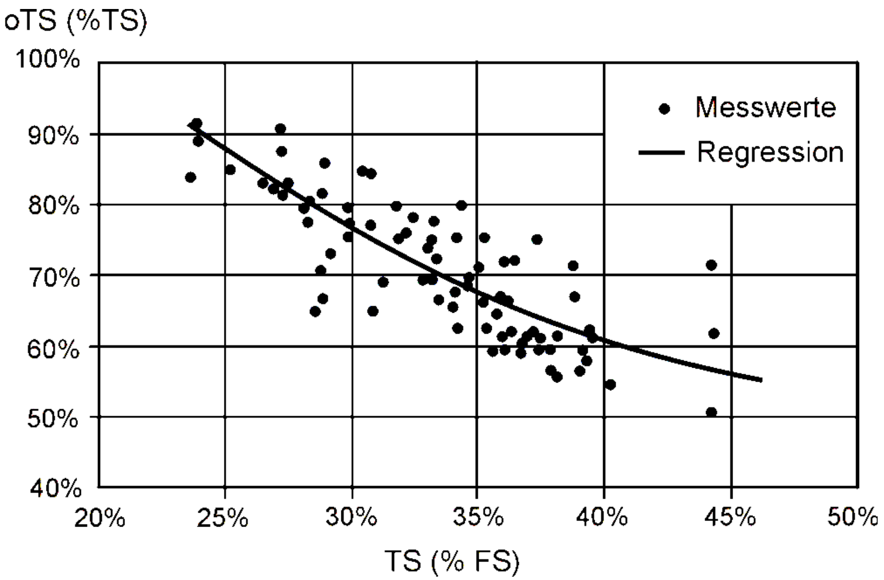
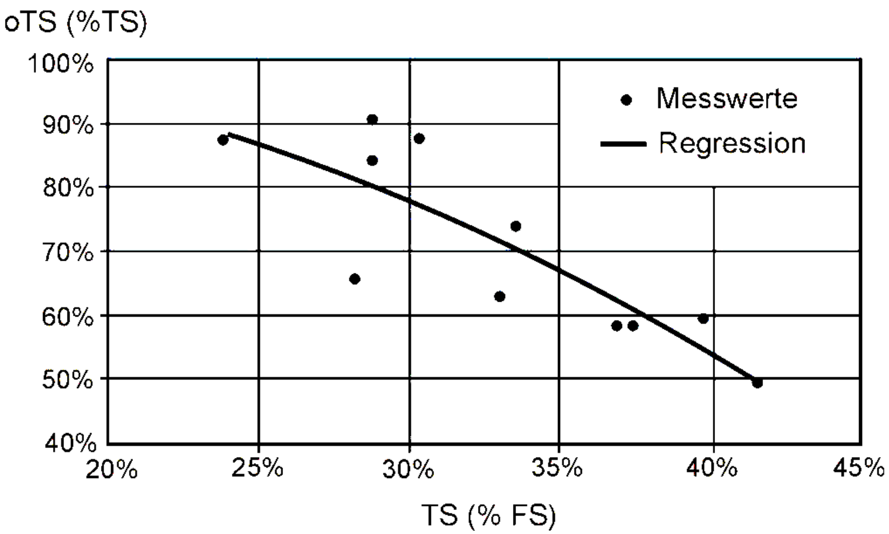


# Anaerobic degradable, org. substance (oTSana)
# 厌氧可降解有机物质 (oTSana)




empirically: the higher the content of dry matter in waste, the lower is the percentage of oTS / TS
经验：固废中固体含量越高，有机质 / 固体总物的比例越低

empirically: the higher the content of dry substance in waste the lower the percentage of oTSana / oTS
经验：固废中固体含量越高，可降解有机物 / 有机物总量比例越低





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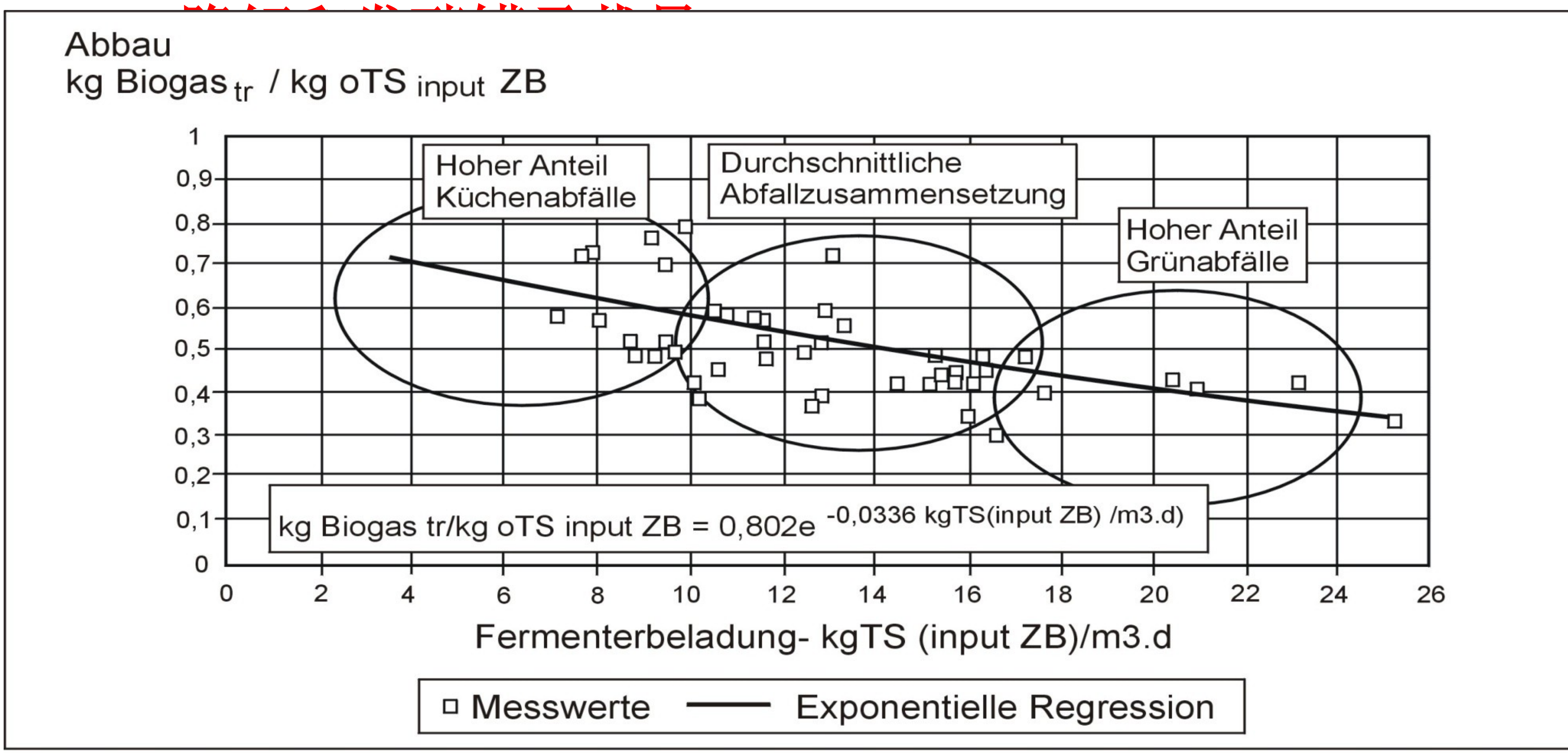
# Degradation and fermenter loading



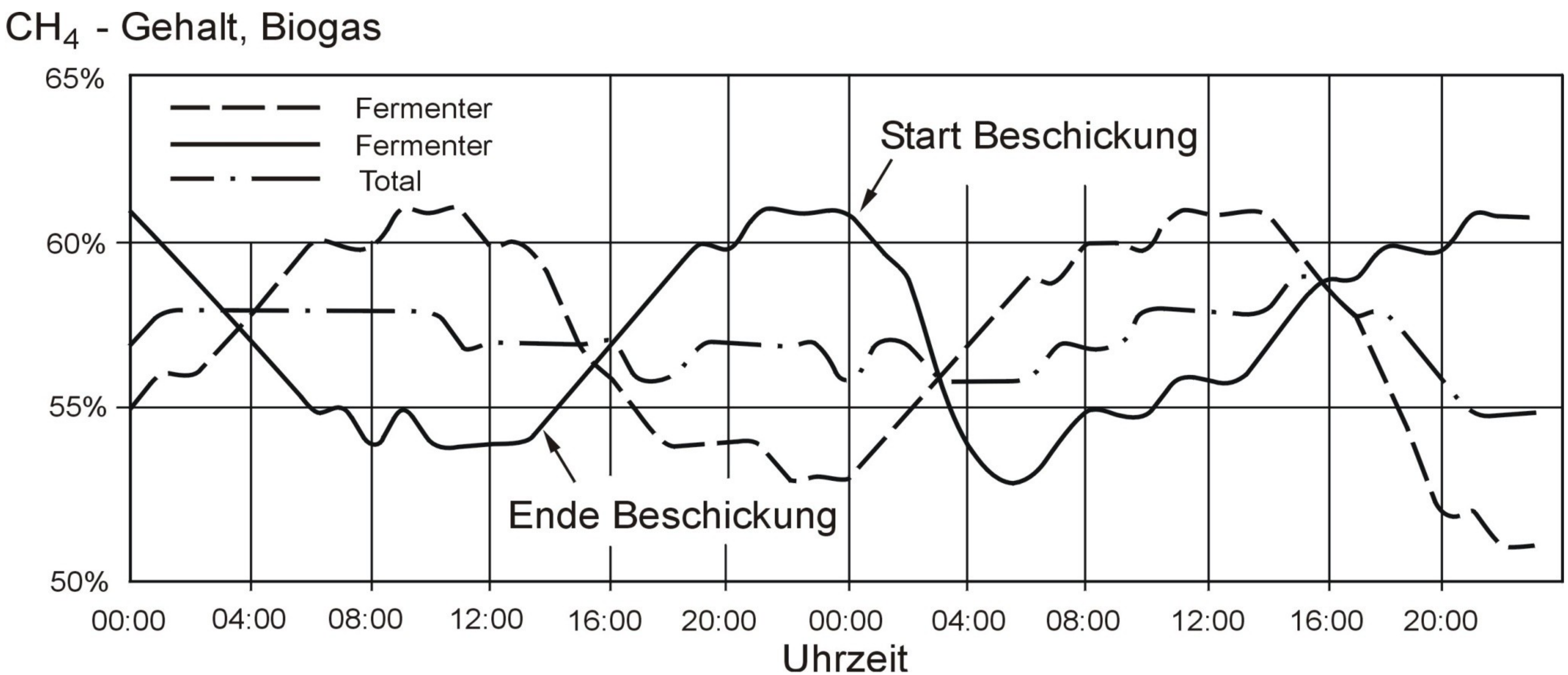

Fermenter loading: 5 kg $oTS_{ana}$ / m³*d

发酵罐的承载量 5 kg oTSana / m³*d

# $CH_4$-content with discontinuous loading

# 间歇式底物输入法中的甲烷含量






The example shows a12h – loading cycle in a plant with two fermenters.

这个例子选自一个有两个发酵罐，每 12 小时输入一次底物的发酵厂

# $CH_4$-content with discontinuous loading
# 间歇式底物输入法中的甲烷含量

The advantage of this procedure is, that the process can be well evaluated on the basis of the increase and the highest and lowest points.

这种方式的优势是，最高点和最低点明显，有利于过程分析

**Process situation good:** steep increase in $CH_4$-content after end of loading, highest and lowest points almost same daily

过程非常好：甲烷含量由于输入底物而提高得很快，每天的最高点和最低点几乎相同

**Prozess situation bad:** few distinct time variation curves daily, accompanied by continuously sinking average values

过程不好： 每天明显的含量曲线很少，均值一直降低

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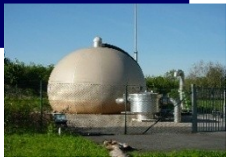
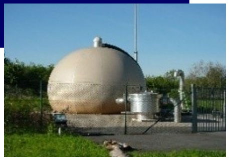


# Guiding and limiting values, waste(I) according to...

# 目标值和极限值，固废（I）根据

| Value | Unit | Av. value | Mini-mum | Maxi-mum | remarks |
|---|---|---|---|---|---|
| C/N-ratio | | 18 | 15 | 25 | Too low: Ammonium inhibition 太低，氨抑制 |
| Kjeldahl-N | mg/kg | 3500 | - | 4000 | Too high: increased formation of ammonium 太高，强烈氨抑制 |
| oTS-content | % | 70 | 65 | 75 | Too high: too high ferment load with $oTS_{ana}$ 太高，发酵罐有机物输入过多 |
| TS-content 庭院垃圾 | % | 32 | 30 | 40 | Too low: uncontrolled flow in the intermediate bunker Too high: hydraulic loading and TS-charge too high 太低：存储过程不可控制；太高：水解的承载量和总固输入过高 |
| Green waste | % | 30 | 20 | 40 | raises C/N ratio 碳氮比升高 |
| impurities > 2 mm 干扰物 | % | 7 | 0 | 12 | |
| ph-value | - | 6 | 5 | 7 | tlow: points out to hydrolytic processes in waste 过低：固废的水解过程 |



# Guiding and limiting values, waste (I) according to ...

# 目标值和极限值，固废（II）根据

-C/N ratio, TOC over K-N
(Total Organic Carbon / Kjeldahl-Nitrogen)

碳氮比，总有机碳 / K 氮

-Ammonium is formed from K-N (measured in biowaste),
NH4/K-N is higher the higher the K-N

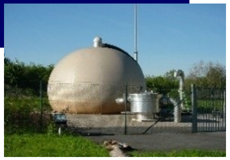
氨含量产生于 K 氮（有机垃圾中测量） NH4/K-N 越高， K 氮含量越高

-oTSana/oTS is higher the higher oTS

可降解有机物含量 / 有机物含量越高， 有机质含量越高

Organic acids and ammonium can be determined in their relevant concentrations only in the anaerobic stage, therefore only analyze the ferment substrate

有机酸和氨可以根据厌氧过程中的相关浓度而确定，因此只能分析发酵罐物质



# Guiding and limiting values, Fermenter (II)

# 目标值和极限值，发酵罐（II）

| Value | Unit | Av. value | Minimum | Maximum | remarks |
|---|---|---|---|---|---|
| TS-content In reciever tank | % | 26 | 24 | 30 | Visual assessment of viscosity 视觉判断 |
| TS-content at At fermenter entry | % | 24 | 22 | 26 | Strongly depends on waste composition 根据固废组成而定 |
| Substrate temperature in fermenter | °C | 56 | 54 | 57 | Optimum temperature also depends on C/N ratio: close C/N ⇒ > low temperatures 优化温度和 C/N 有关，C/N 低，温度低 |
| Temperature Of heating area | °C | | | 68 | Sterilisation above 68 °C 灭菌温度 68 度以上 |
| Acetic acid 乙酸 Ferment entry | mg/l | 3000 | | 4000 | 乙酸浓度应该高于丙酸 |
| Propionic acid Ferment entry 丙酸，发酵罐输出 | mg/l | 2000 | | 2500 | Acetic acid concentration should always be higher than that of Propionic acid |
| pH-value ferment entry | - | 7.3 | 7 | 7,6 | Lower values only with lower $NH_x$ concentration allowed 只有 NHx 浓度低，此值才 |

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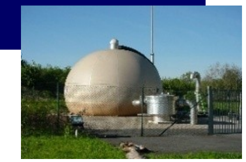
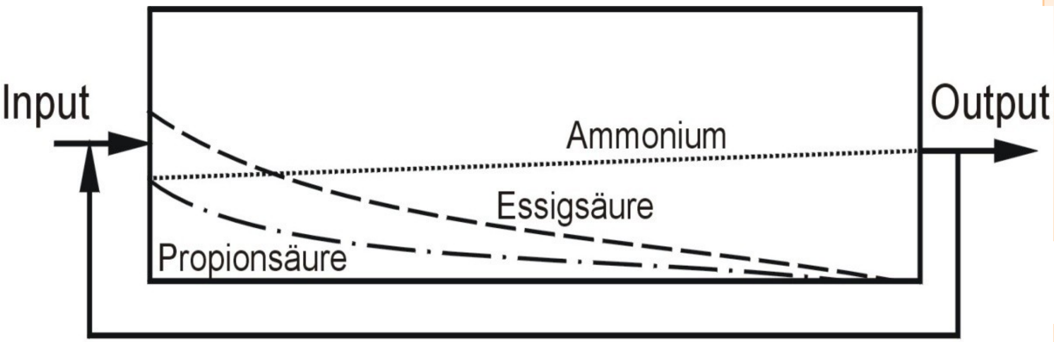
# Guiding and limiting values, Fermenter (III)

# 目标值和极限值，发酵罐（III）

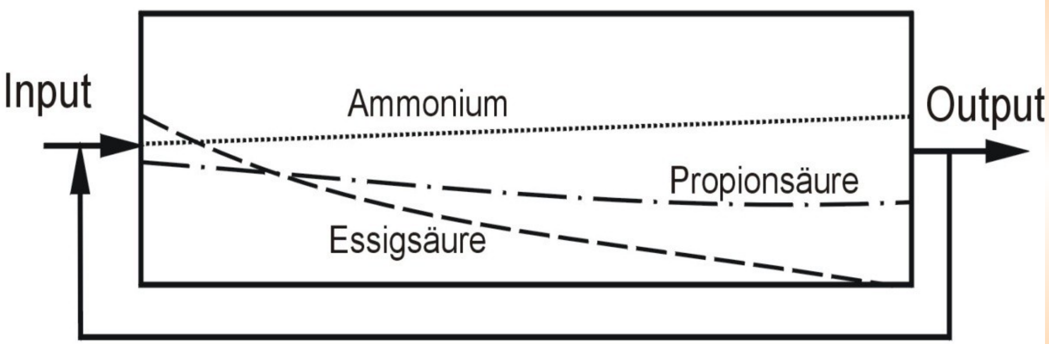
| value | unit | Av. value | Mini-mum | Maxi-mum | remarks |
|---|---|---|---|---|---|
| Acetic acid 乙酸 发酵罐输出 Fermenter exit | mg/l | 10 | | 100 | 高浓度对开始阶段造成影响很大 |
| Propionic acid 丙酸，Fermenter exit 发酵罐输出 | mg/l | 100 | | 500 | Danger of a step up with higher concentrations |
| pH-value Fermenter exit | - | 7.4 | 7.2 | 7.8 | 数月可适应高值 |
| Ammonium $NH_x$-N 氨 | mg/l | 2000 | | 2600 | Adaption to higher values possible over many months |
| Fermenter load with $oTS_{ana}$ | kg/(m³x d) | 5 | | 6,3 | assumption: complete conversion of $oTS_{ana}$ to Biogas 设想：所有的有机物都转化为生物气 |
| Biogas output | Nm³/Mg | 110 | | 139 | Density of biogas: 1.24 kg/Nm³ 生物气密度 |
| iron | mg/l | > 0,5 | | | Guiding value |
| Nickel | mg/l | > 0,3 | | | Guiding value |
| cobalt | mg/l | > 2,3 | | | Guiding value |
| Molybdenum | mg/l | > 0,5 | | | Guiding value |



# Acid profile and influence of Ammonium
# 酸的特征和氨影响



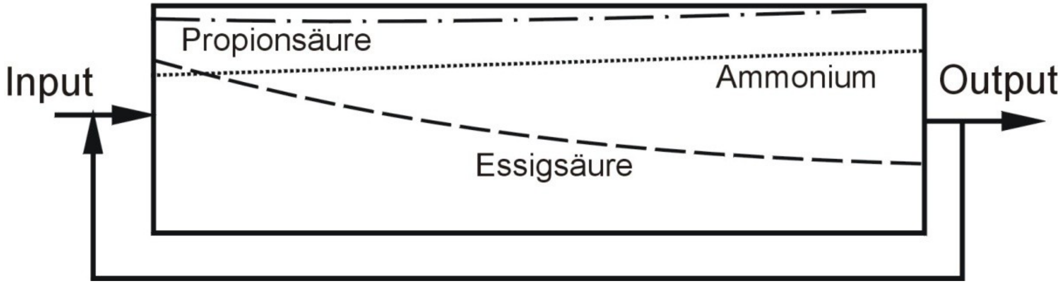

**Normal behaviour !**
Acid reduction takes place
With the expected profile
正常状态！
酸浓度降低和预测特征一样 .




**First signs acidification !**
Propionic acid reduction shows
Very little profile, whereas acetic
Acid gets reduced well.
First measures to be taken
酸化的特征！
丙酸浓度降低特征不明显， 与此同时乙酸降解好。首先采取措施

# Acid profile and influence of Ammonium

## 酸的特征和氨影响




**Advanced acidification !**
Propionic acid increases instead of decreasing , reduction of acetic acid is strongly affected. Urgent Measures to be taken
进一步酸化！
丙酸浓度增加而不是降低，
乙酸影响较大。需要马上
采取措施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