



EUROPEAN
REGIONAL
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Dairy Wastewater Treatment in Poland

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BEST – Better Efficiency for Industrial Sewage Treatment

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Dairy industry in Poland

Until the 19th c. people made dairy products in their households and used them for their own purposes. The development of cities created a need to develop of the dairy industry.

1875- first milk factories are built in Poland

Before 1918, there were 770 milk factories in Poland. Butter and cream were exported then

Before 1939, there were 1475 milk factories

1944 –only 40% of milk factories are left

After the war 685 milk factories function

2004 – Poland joins the EU. That year, 134.6 thousand farmers deliver the milk to
265 milk factories

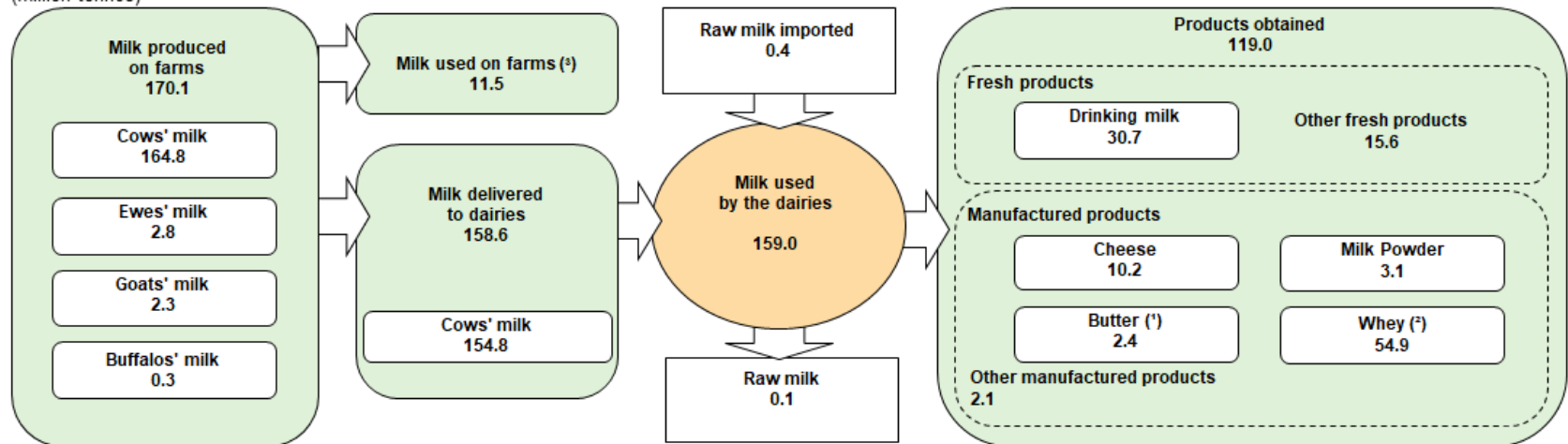
2017- 175 dairies employ over 32,000 people

2018 -184 dairies

PRODUCTION AND USE OF MILK IN EU

In 2017, farms across the EU-28 produced 170.1 million tonnes of milk, of which 164.8 million tonnes was cows' milk. 158.6 million tonnes of milk was delivered to dairies

Production and use of milk, EU-28, 2017
(million tonnes)



(*) Eurostat estimate for Ireland.

(*) Includes other yellow fat dairy products; expressed in butter equivalent.

(*) In liquid whey equivalent.

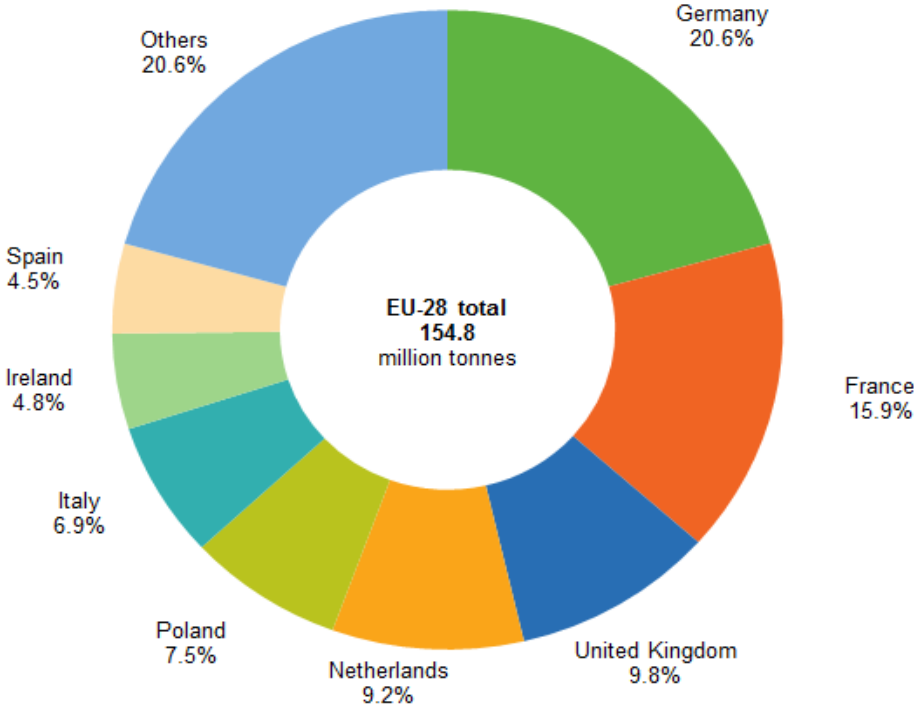
(*) In whole milk equivalent.

Source: Eurostat (online data codes: apro_mk_pobta and apro_mk_farm)

COW'S MILK PRODUCTION IN EU

Cow's milk plays the dominant role in Polish production and processing

Collection of cows' milk by dairies, 2017
(% share of EU-28 total, tonnes)



Source: Eurostat (online data code: apro_mk_pobta)

MILK PRODUCTION IN POLAND

- I. **2,15 million** cows produce **12,4 million tonnes** of milk, which locate Poland as:
- the **5th** largest producer in the EU,
 - the **12th** producer in the world
- II. Milk production in Poland accounts for:
- **2,1 %** of the world production,
 - **7,5 %** of EU production,
 - **about 12%** of total agricultural production in Poland.



EU LEGISLATION IN THE AREA OF WASTEWATER DISCHARGE AND TREATMENT

The Council Directive 91/271/EEC of May 21st, 1991 concerns urban wastewater treatment.

The purpose of the Directive is to protect the aquatic environment from pollution by the discharged wastewater.

The Members of the European Union are required to fulfill the objectives of the Directive 91/271/EEC on the scheduled date.

POLISH LEGISLATION IN THE AREA OF WASTEWATER DISCHARGE AND TREATMENT

Following the EU Directive, **The National Urban Wastewater Treatment Programme** was endorsed in Poland on the 16th of December, 2003.

POLISH NATIONAL URBAN WASTEWATER TREATMENT PROGRAMME

Dates in the Programme are the following :

1. Until the 31st of December, 2015 all communities \geq 2000 PE (Population Equivalent) must be equipped with sewerage systems and municipal treatment plants,
2. Until the 31st of December, 2015 the reduction in total nitrogen and a total phosphorus from municipal wastewater discharged into water shall equal 75%
3. Until the 31st of December, 2015 communities $<$ 2000 PE which had already been fitted with sewage systems before the Polish accession to the EU should have suitable treatment of wastewater,
4. Until the 31th of December, 2010 food-processing industries larger than 4000 PE are required to reduce biodegradable pollution.

Reduction of nitrogen and phosphorus is the priority in this Programme.

The dairy production in Poland generated 26.5 hm³ of sewage

14.7 hm³ was treated
11.8 hm³ was discharged into sewage system

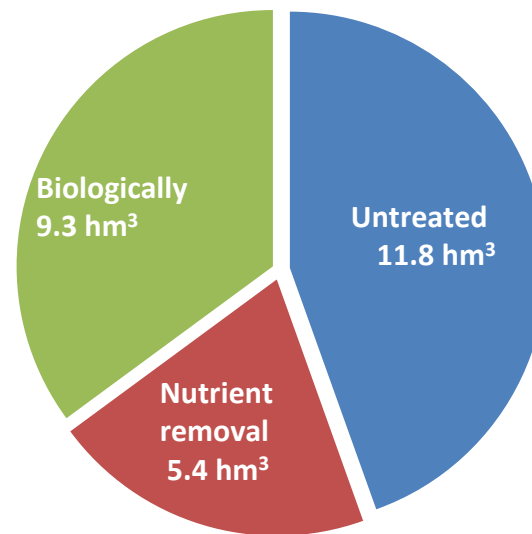


Figure 1 Wastewater generated during dairy production in Poland

Table 1 Dairy wastewater characteristics

Parameter	Type of production						
	1	2	3	4	5	6	7
pH	7,0	6,4	6,6	7,5	7,6	7,2	7,2
COD gO ₂ /m ³	3950	1360	3420	1055	2090	1450	2090
BOD ₅ g O ₂ /m ³	1760	1300	1900	690	1135	875	1160
Oil and grease g/m ³	150	31	100	75	32	375	60
TSS g /m ³	350	400	485	200	505	1980	205
TS g /m ³	2020	1800	1920	1100	1090	3250	1460

1 – cheese

2 – casein

3 – cottage cheese

4- butter

5- milk puder

6 – processed cheese

7 – milk

Table 2 Wastewater composition from cheese production

Parameter	Without cheese whey	With cheese whay
COD mgO ₂ /L	5312	20559
BOD ₅ mgO ₂ /L	2397	5312
Oil and grease mg/L	96	463
Total nitrogen mg/L	90	159
Total phosphorus mg/L	26	21

Table 3 Maximum value of parameters in treated dairy wastewater discharged to the waterway, according to the Polish Regulation (of selected substances)

Contaminant mg/L	Regulation of PL MoE, 2014
BOD	25
COD	125
TSS	30
Total N	30
N-NH ₄ ⁺	10
Total P	2
Oil and grease	20

Stages of dairy wastewater treatment

a) Mechanical treatment

- screening,
- grit removal,
- flotation,
- equalization,

b) Biological treatment

AEROBIC

- trickling filter,
- activated sludge,
- SBR (sequential batch reactors),
- oxidation ditches,

ANAEROBIC REACTORS

c) Secondary treatment

Examples of WWTP in Polish dairies

DAIRY I



The factory produces cheese of different size and shape:

- » round form: weight 3-8 kg,
- » rectangular: weight 1-4 kg,
- » pieces: weight 250 g,
- » triangular: 190 g,
- » slices: 150 g.

Powder products:

- » skimmed milk ,
- » whole cream milk,
- » cheese whey,
- » butter milk,
- » whey,
- » whey protein concentrate,
- » whey permeate.

Table 4.Flow assumed for the project

Average flow	m ³ /d	2380
Maximum flow	m ³ /d	3000

Table 5.The concentration and the load of contamination assumed for the project

Parameters	Concentration mg/L	Load kg/d
BOD	1500	4500
TSS	550	1650

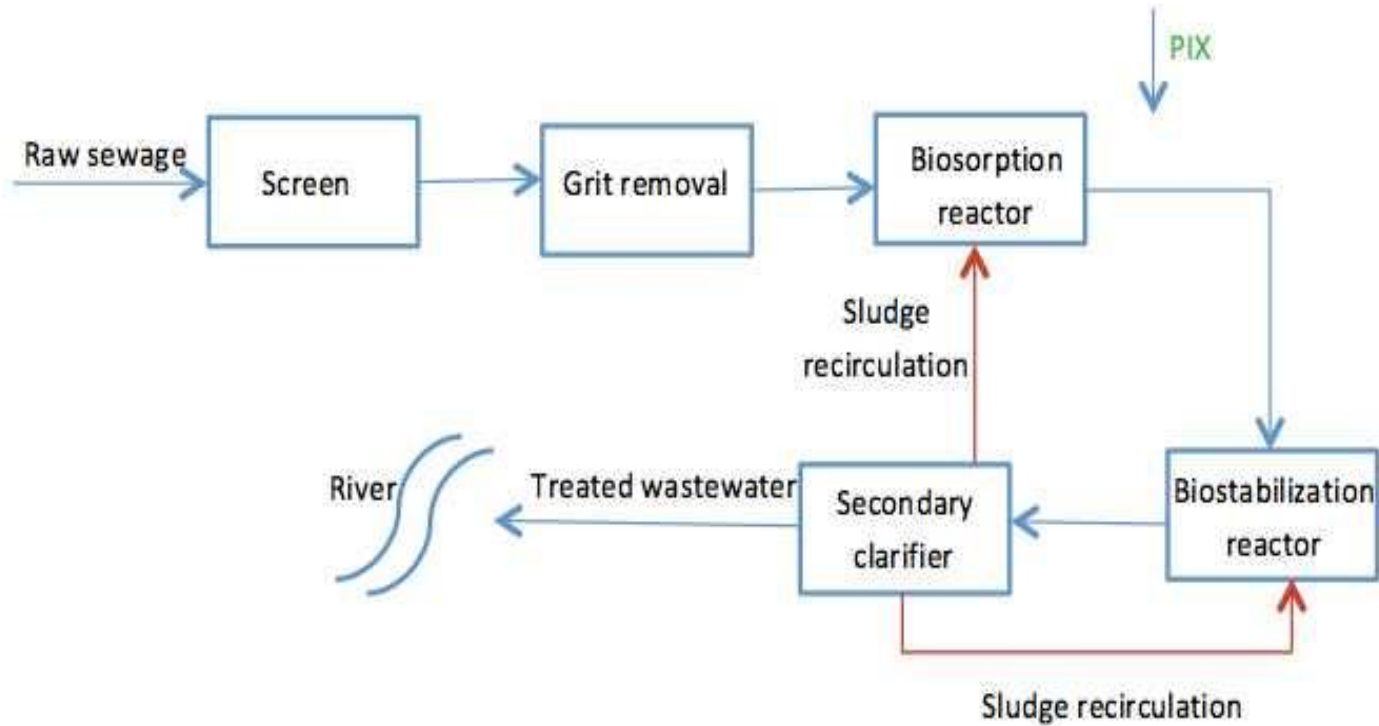


Figure 2 Block of scheme WWTP for DAIRY I

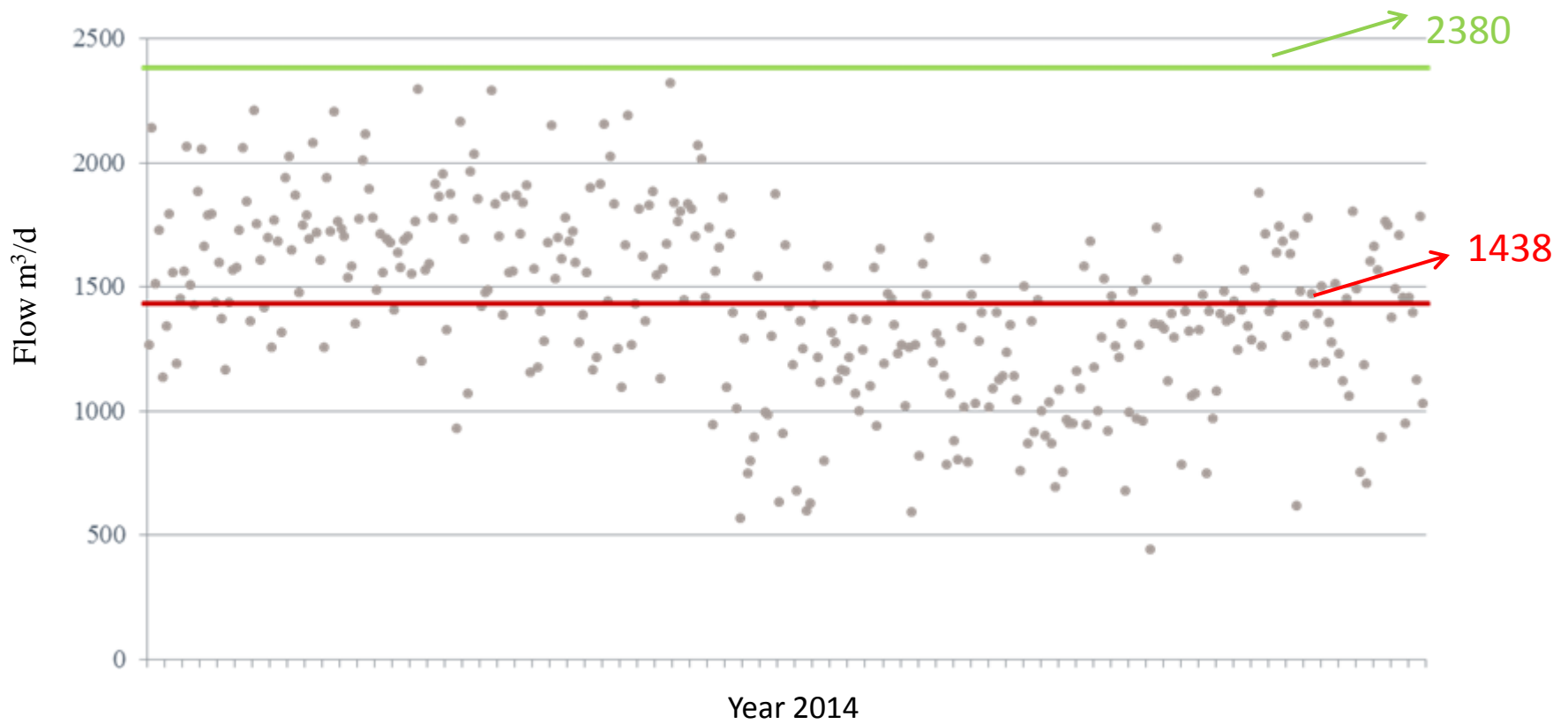


Figure 3 Actual flow to WWTP from DIARY I

Table 6 Characteristics of raw wastewater from DAIRY I

Parameter	Concentration [mg/L]		
	min	max	average
BOD	1120	2890	2077
COD	1883	6555	3212
TSS	221	557	422
TN	89	321	177
TP	16	107	38

Table 7 Characteristics of effluent from WWTP for DAIRY I

Parameter	Limit according Polish regulation [mg/L]	Concentration [mg/L]		
		min	max	average
BOD	25	5	23	15
COD	125	19	122	68
TSS	35	14,8	27	21,1
TN	30	1,6	8,8	4,1
TP	2	0,5	1,9	1,1

DAIRY II



Production in this factory includes:

- Milk,
- Milk powder,
- Cheese,
- Butter,
- Cream.



Table 8.Flow assumed for the project

Average flow	m ³ /d	750
Maximum flow	m ³ /d	1200

Table 9.The concentration and the load of contamination assumed for the project

Parameters	Concentration mg/L	Load kg/d
BOD	1500	1125
COD	3500	2625
TN	150	112,5
TP	20	15

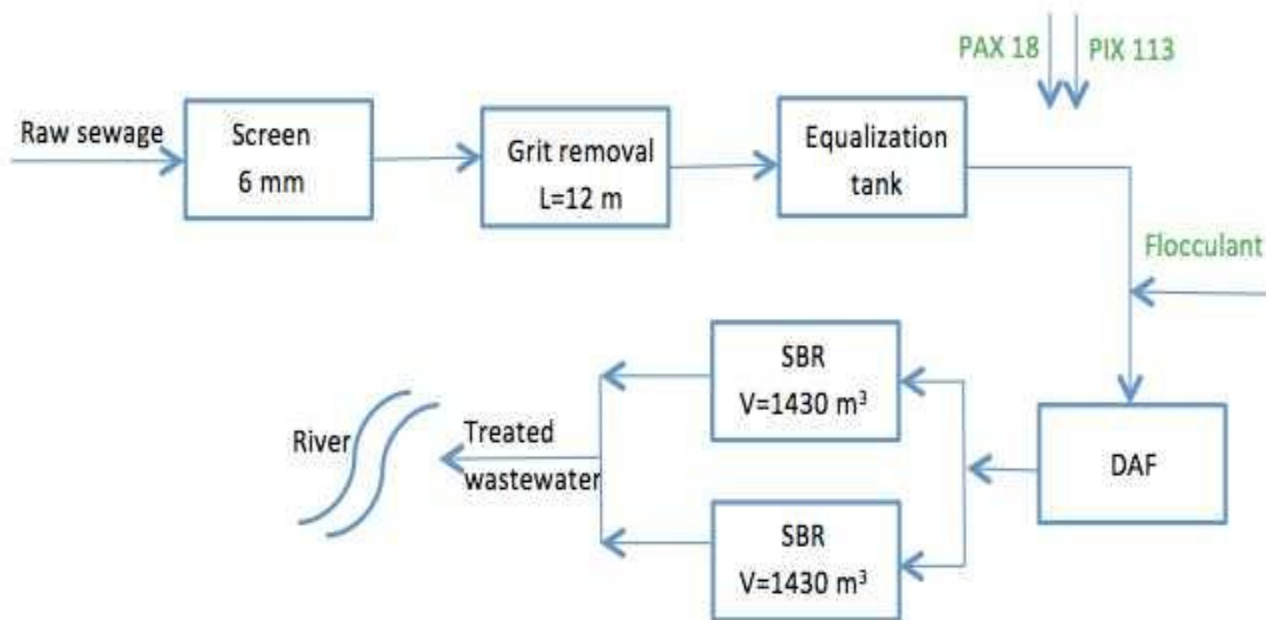


Figure 4 Block of scheme WWTP for DIARY II



Drum screen



Grit removal



Equalization tank



DAF

Table 10 Actual flow to WWTP from DIARY II

Month	Q_{\min}	Q_{av}	Q_{\max}	n
January	479	727	985	31
February	451	667	1051	28
March	431	621	1072	31
April	530	855	1125	30
May	413	890	1826	31
June	372	656	906	30
July	453	843	1349	31
August	295	681	1073	31
September	116	545	1282	30
October	278	540	2243	31
November	214	488	914	30
December	353	571	962	31
Year	116	678	2243	365

Table 11 Characteristics of raw wastewater in DAIRY II

Parameter	Concentration [mg/L]		
	min	max	average
BOD	43	2700	1105
COD	712	3800	1905
TN	8,5	647 next(400)	122
TP	3,57	40	16,7

Table 12 Characteristics of effluent from WWTP for DAIRY II

Parameter	Limit according Polish regulation [mg/L]	Concentration [mg/L]		
		min	max	average
BOD	25	3	25	10
COD	125	7	124	31
TN	30	1,6	29	11,8
TP	2	0,2	1,9	0.8

3,1-3,4 m³ wastewater/ 1000L milk

6,8-8,1kgCOD/ 1000L milk

DAIRY III

Production in this factory includes:

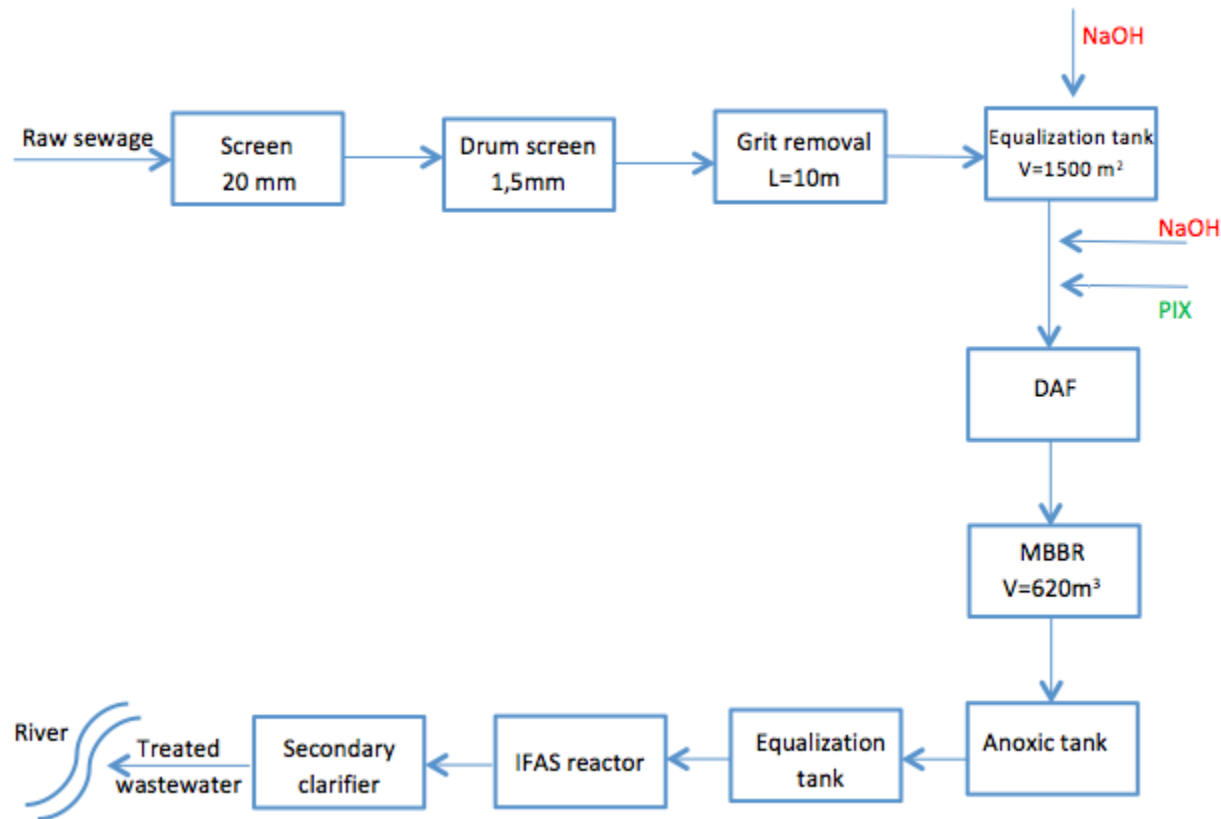
- Milk,
- Milk powder,
- Cheese,
- Cottage cheese,
- Butter,
- Cream,
- Yoghurt,
- Cheese whey.

Table 13.Flow assumed for the project

Average flow	m ³ /d	3000
Maximum flow	m ³ /d	4000

Table 14.The concentration and the load of contamination assumed for the project

Parameters	Concentration mg/L	Load kg/d
BOD	2000	6000
COD	3200	9600
TSS	1000	3000
TN	180	540
TP	80	240



MBBR- Moving Bed Biofilm Reactor
 IFAS –Integrated Fixed Activated Sludge

Figure 5 Block of scheme WWTP for DIARY III

Table 15 Actual flow to WWTP for DIARY III

Month/Year	Q min m3/d	Q max m3/d	Q average m3/d
10.2015	2304	3960	3451
11.2015	3120	4080	3626
12.2015	3240	4416	3946
01.2016	3288	4440	4084
02.2016	3552	4320	4025

Table 16 Characteristics of raw wastewater in DAIRY III

Parameter	Concentration [mg/L]		
	min	max	average
pH	6,5	10,2	8,2
COD	2119	6128	3774
TN	39,4	362	122
TP	13,1	80,0	44,0
TSS	620	3420	1558

DAIRY IV

In this dairy there are produced: cheese, cottage cheese and butter.



DAIRY V

In this dairy there are produced: milk, sour cream, yoghurt, milk powder, cheese whey powder, cheese, butter.



Table 17.Flow assumed for the project

Average flow	m ³ /d	1500
Maximum flow	m ³ /d	1650

Table 18.The concentration and the load of contamination assumed for the project

Parameters	Concentration mg/L	Load kg/d
BOD	2200	3300
COD	3500	5250
N total	100	150
P total	40	40

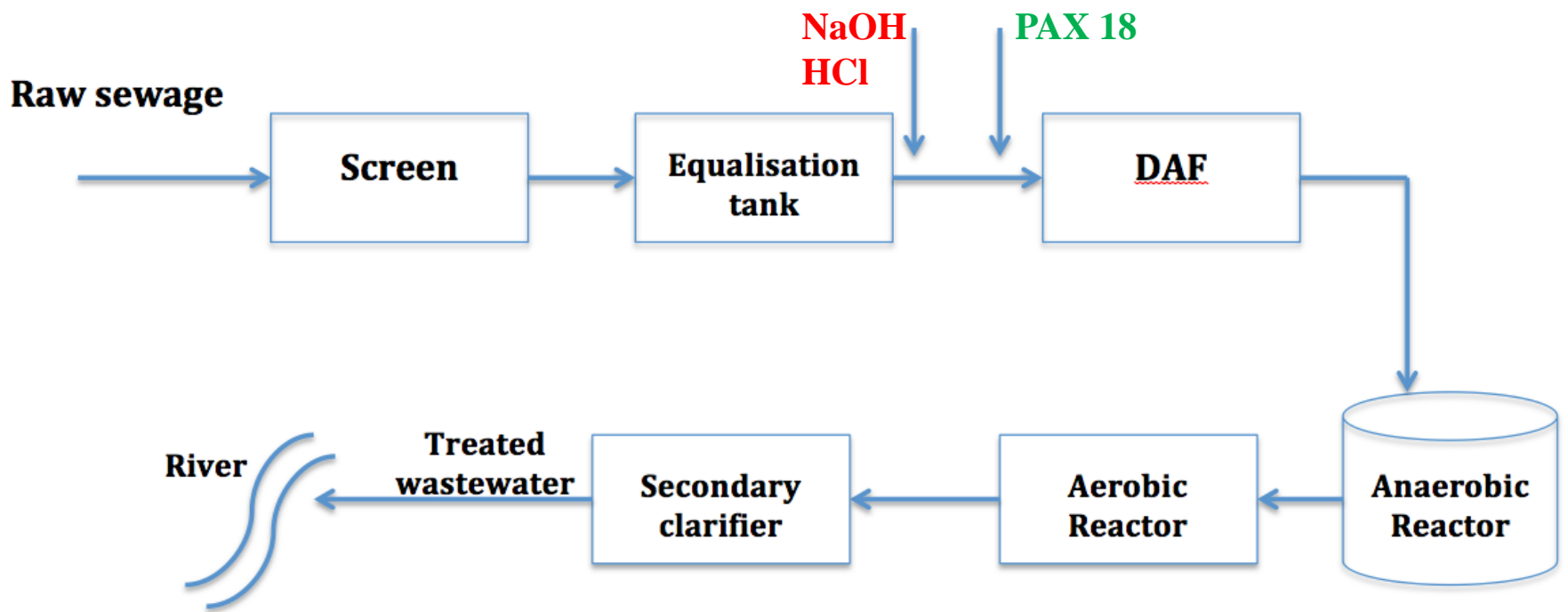
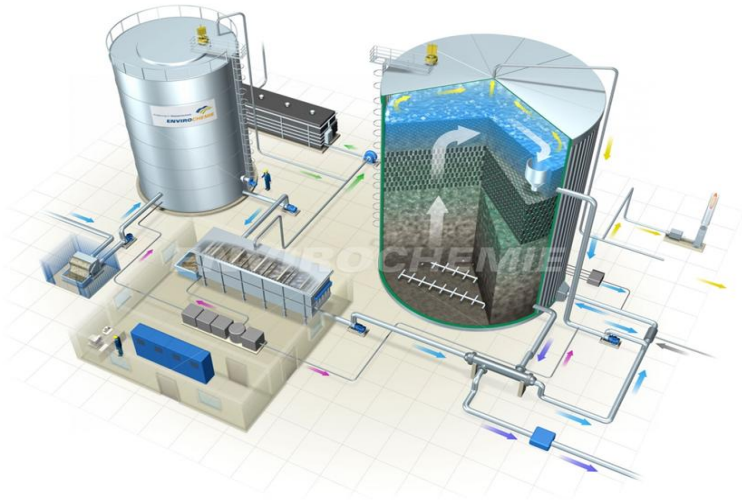


Figure 6 Block of scheme WWTP for DIARY IV and V

BIOLOGICAL TREATMENT

DAIRY IV

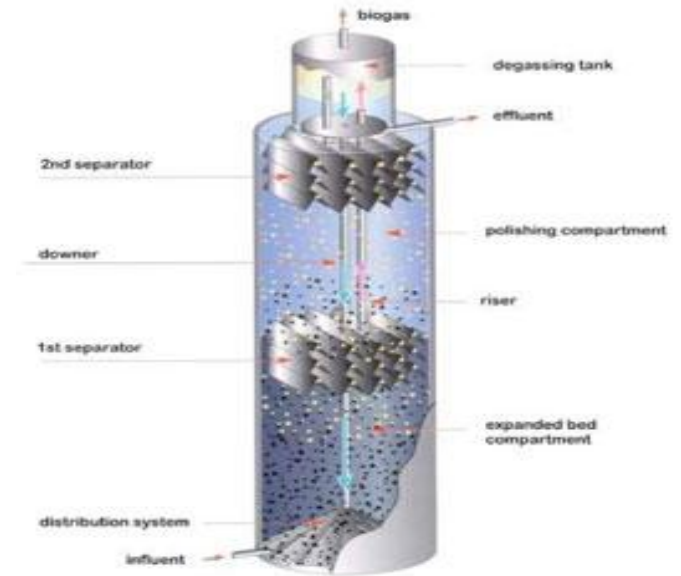
$V = 1698 \text{ m}^3$
 $OLR = 4 \text{ kgCOD/m}^3 \cdot \text{d}$
 $HRT = 21,6 \text{ h}$
 $T = 30-35^\circ\text{C}$



ANAEROBIC REACTOR

DAIRY V

$V = 300 \text{ m}^3$
 $OLR = 11-30 \text{ kgCOD/m}^3 \cdot \text{d}$
 $HRT = 4,8 \text{ h}$
 $T = 32^\circ\text{C}$



AEROBIC REACTOR

$V = 1000 \text{ m}^3$
Anoxic tank $V = 270 \text{ m}^3$,
Aeration tank $V = 730 \text{ m}^3$

$V = 2000 \text{ m}^3$
Anoxic tank $V = 500 \text{ m}^3$
Aeration tank $V = 1500 \text{ m}^3$

Table 19 Actual parameters in raw wastewater

Parameter	Value		
	min	max	average
COD mg/L	1513	5056	2310
LCOD kg/d	1708	7640	3173
TN	25,7	39,8	35,7
TP	14,3	18,4	17,4

DAIRY IV

DAIRY V

Parameter	Value		
	min	max	average
COD mg/L	1329	8639	4001
LCOD kg/d	1984	12166	5676
TN	26,0	148,0	99,0
TP	11,4	60,0	26,9

Table 20. Actual parameters in wastewater influent and effluent to anaerobic reactors (**DAIRY IV**)

Parameters	MIN	Average	MAX
COD _{inf} mg/L	933	1886	3417
LCOD _{inf} kg/d	1053	2592	5163
COD _{eff} mg/L	813	1279	2017
LCOD _{eff} mg/L	973	1744	3181
VFA _{eff} mgCH ₃ COOH/L	200	437	811
OLR _{ANR} kgCOD/m ³ ·d	0,8	1,9	3,8
Temperature °C	27,0	31,2	34,3
HRT h	18,1	24,1	32,8
Biogas production m ³ /d	169	396	897

Table 21. Actual parameters in wastewater influent and effluent to anaerobic reactors (**DAIRY V**)

Parameter	MIN	Average	MAX
COD _{inf} mg/L	561	2394	4841
LCOD _{inf} kg/d	716	3475	7234
COD _{eff} mg/L	431	1768	3597
LCOD _{eff} mg/L	587	2528	5344
VFA _{eff} mgCH ₃ COOH/L	143	427	892
OLR _{ANR} kgCOD/m ³ ·d	2,7	13,1	32,1
HRT h	2,6	5,1	6,4
Biogas production m ³ /d	326	1412	5477

Factory produces

- Milk powders;
- Cottage cheese;
- Butter and milk fats;
- Cream;
- Milk and milk drinks.



Assumptions for the project

Average flow

$$Q_{av} = 1500 \text{ m}^3/\text{d}$$

Tabela 22 The concentration and the load of contamination assumed for the project

Parameter	Concentration [mg/L]	Load [kg/d]
COD	8300	12450
TN	238	425

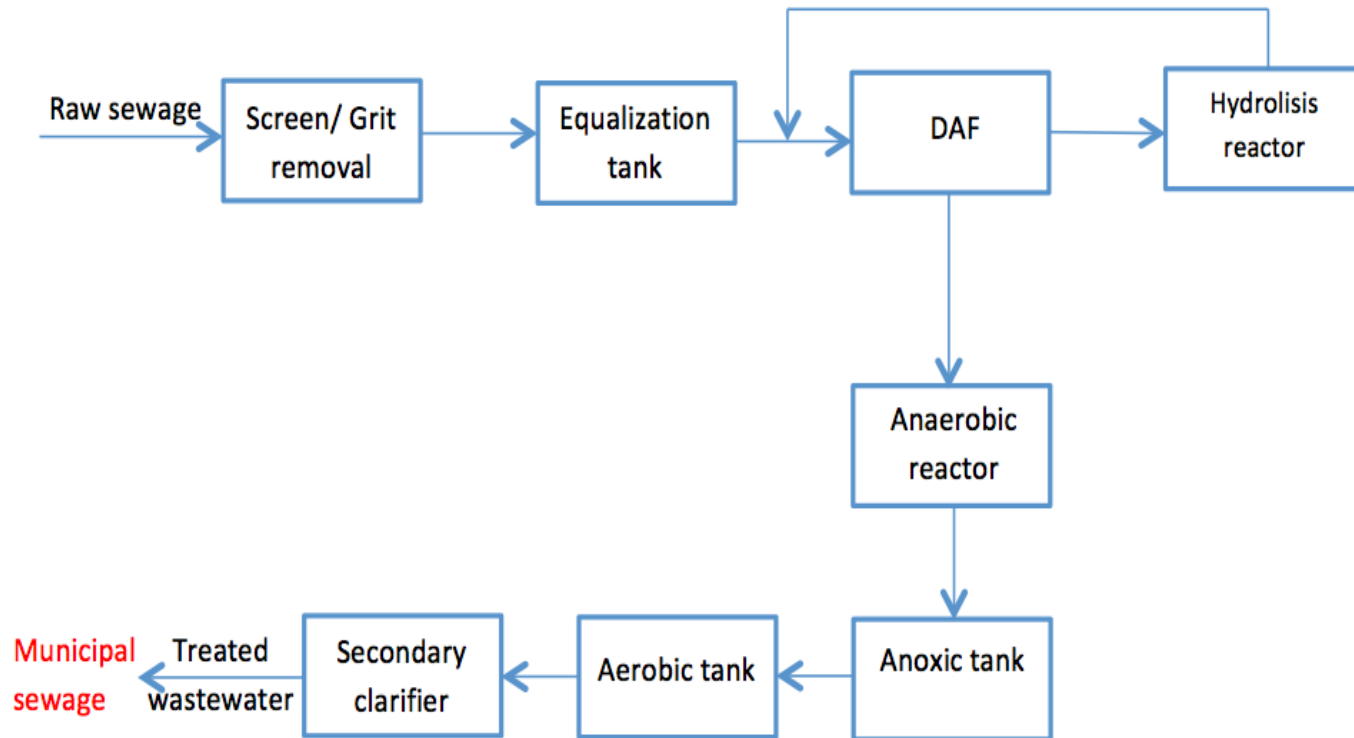
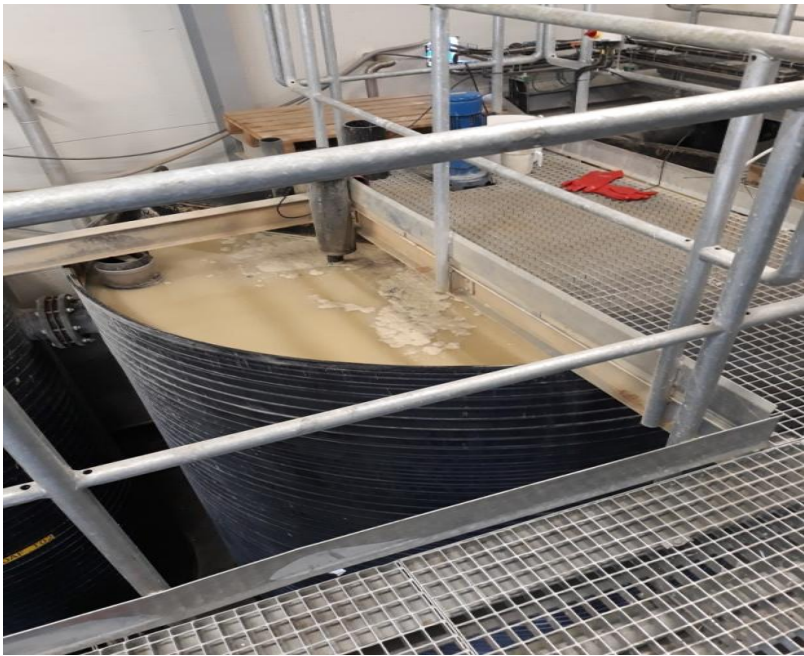


Figure 9 Block of scheme WWTP for DIARY VI



Coagulation tank



DAF



Bufor tank



Anaerobic reactor

Anaerobic reactor parameters

Volume – 2690 m³

Height – 10m

OLR- 3.6 kg COD/m³·d (max 4.2 kg COD/m³·d)

HRT – 1.8 d

Temperature - 23-30°C

Activated sludge reactor

- Anoxic tank – 1140 m³
- Aeration tank - 2356 m³



Anoxic tank



Aeration tank

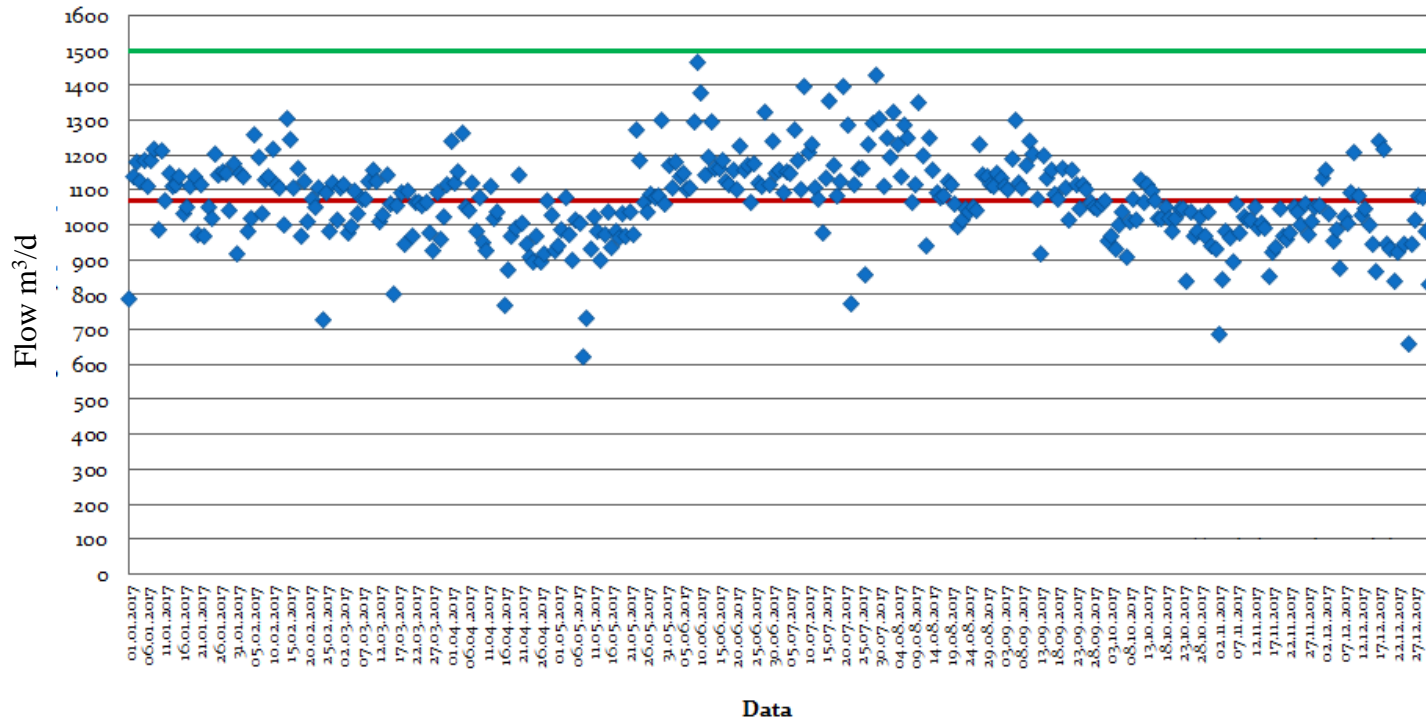


Figure 10 Amount of wastewater flowing into WWTP for DIARY VI



Table 23 Characteristics of raw wastewater from DAIRY VI

Parameter	Concentration [mg/L]		
	min	max	average
pH	4,1	11,4	6,3
COD	3360	11691	6932
TN	104	378	240
TP	13,5	134	82,4
TSS	430	5891	1792

Quality of treated wastewater

- BOD = 570 mg O₂/L
- COD = 800 mg O₂/L
- TSS = 320 mg/L
- TN = 55 mg N/L
- N-NH₄ = 33 mg N-NH₄/L
- TP = 8.5 mg P/L
- Oil and grees = 100 mg/L
- Anionic surfactants = 15 mg/L

Table 24 Characteristics of effluent from WWTP for DAIRY VI

Parameter	Limit according Polish regulation [mg/l]	Concentration [mg/L]		
		min	max	average
COD	800	10	124	42
TN	55	2,2	92,0	15,0

Conclusion

1. In Polish WWTPs the most modern solutions are applied,
2. The removal biodegradable pollutants , nitrogen and phosphorus from dairy wastewater is the main priority in the National Programme,
3. The high quality of treated wastewater allows for the protection of the aquatic environment.



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