Water4Crops

ISWATS 2016; 21ST-23RD APRIL, PUNE, INDIA

SEVENTH FRAMEWORK PROGRAMME

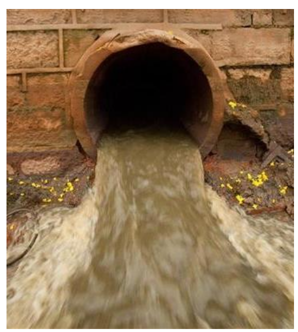
IRSA CNR

WASTEWATER REUSE BY AN INNOVATIVE BIOLOGICAL REACTOR COMBINED WITH SAND FILTRATION

M. De Sanctis*, G. Del Moro, C. Di Iaconi, A. Lopez

*marco.desanctis@irsa.cnr.it

WASTEWATER

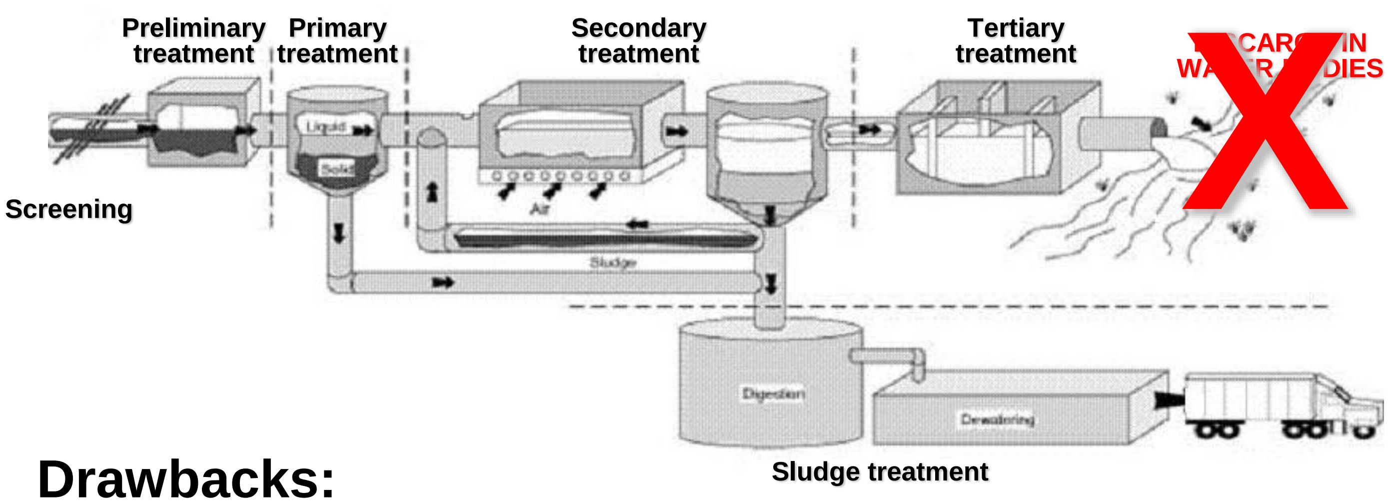


TREATMENT

CROPS

CNR-IRSA: Water Research Institute of the Italian National Research Council

Conventional treatment line



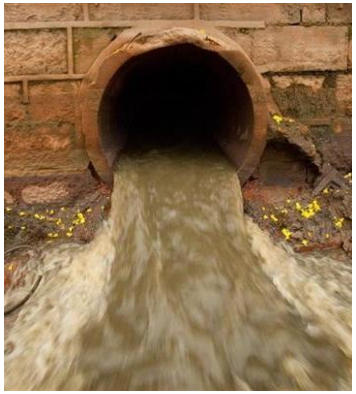
CROPS IRRIGATION

Drawbacks:

- Low settling speed
- Low organic load rate
- High sludge production
- Low flexibility
- High area requirement

Treatment based on Sequencing Batch Biofilter Granular Reactor

WASTEWATER



SCREENING + PRELIMINARY TREATMENT

SBBGR + SAND FILTER

CROPS IRRIGATION

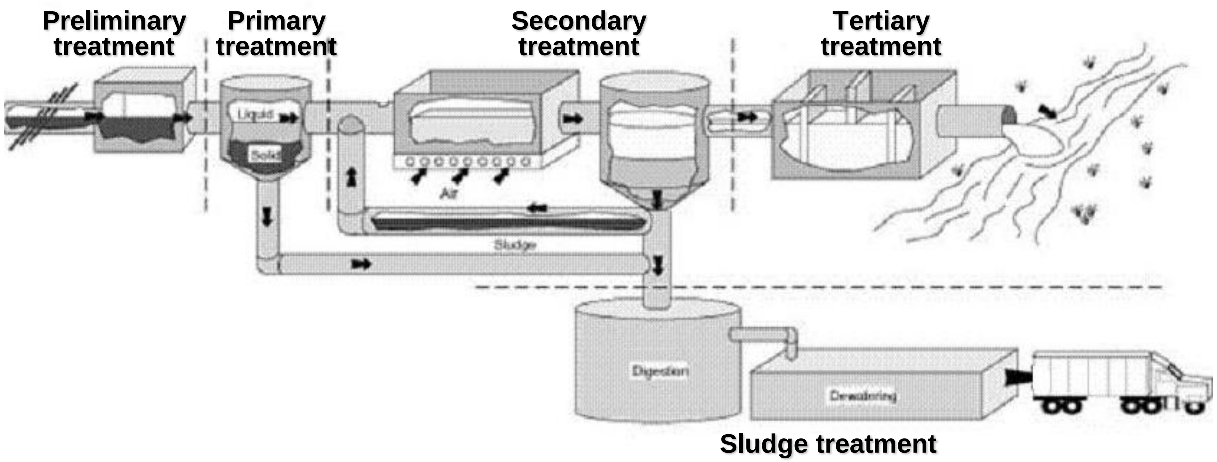
Treatment based on Sequencing Batch Biofilter Granular Reactor

Advantages og SBBGR over conventional AS treatment systems:

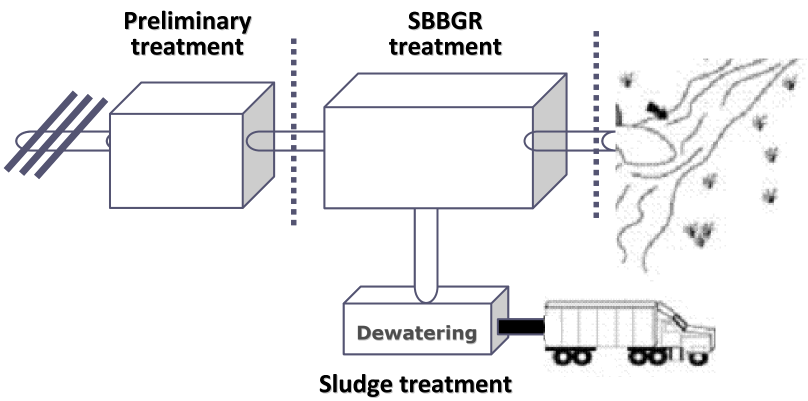
- Perform in a single stage the whole wastewater treatment train (primary and secondary treatments);
- Offer higher operational flexibility and robustness;
- Treat higher organic load rate;
- Reduce the sludge production (up to 80%);
- Produce a high quality effluent;
- Reduce area requirement.

Conventional WWTP VS SBBGR

Conventional WWTP



WWTP based on SBBGR technology



Conventional WWTP VS SBBGR

Parameter	AS	SBBGR
Organic load rate [kgCOD/m^3d]	< 1	2-2.5
Sludge concentration [kgTSS/m^3]	4-5	30-50
Sludge production [kgTSS/kgCOD$_{rem}$]	0.5-0.6	0.1-0.15
Sludge settling speed [m/h]	< 1	Absence of settling unit

AS: Activated sludge.

SBBGR operation - How does SBBGR work?

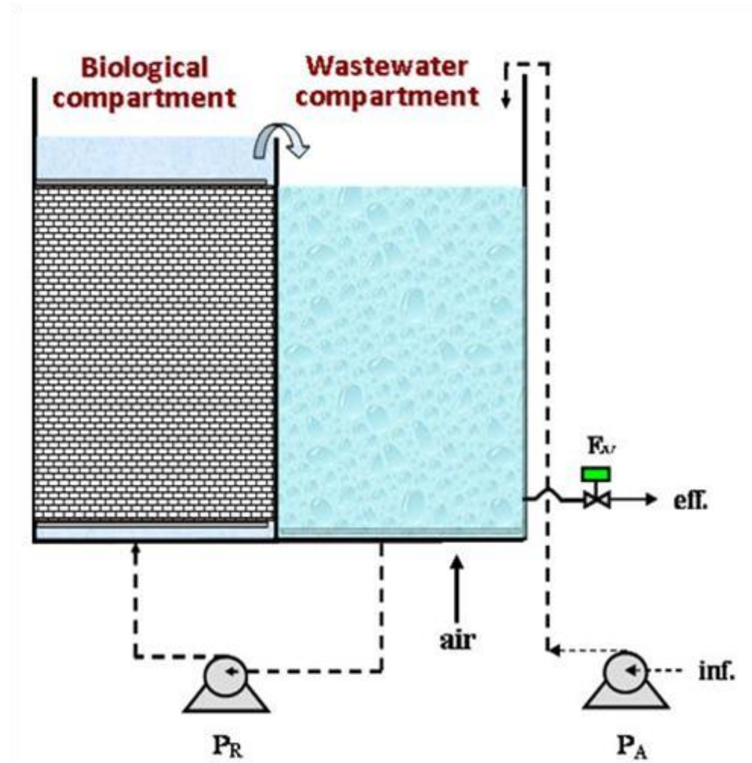
BIOLOGICAL COMPARTMENT (BIOFILTER)

WASTEWATER COMPARTMENT

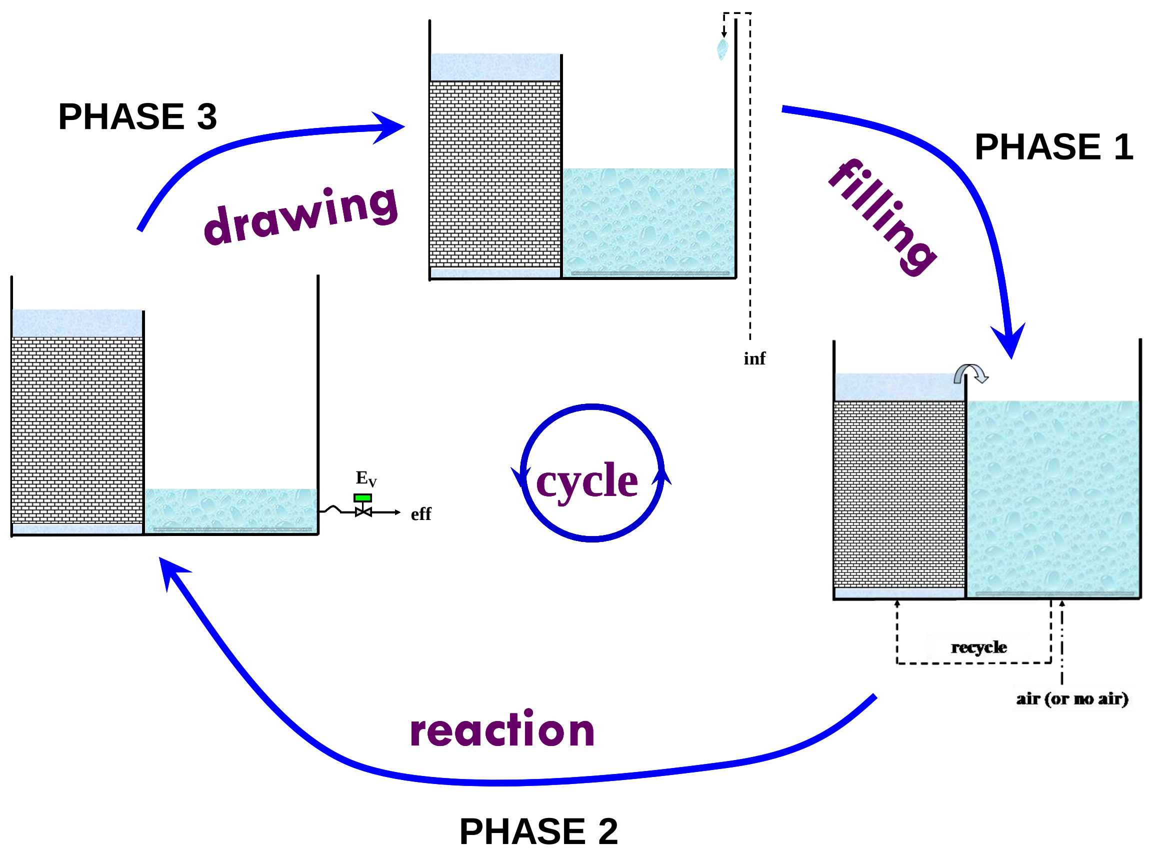
FEEDING PUMP

RECIRCULATION PUMP

BLOWER



SBBGR operation - How does SBBGR work?



SBBGR operation - What makes SBBGR better?

Recirculation flow generates shear stress into packed zone of SBBGR

BIOFILM

GRANULES

- High biomass concentration (30-50 kg/m^3)
- High sludge retention time (≥ 200 d)

Aims

Treatment and reuse in agriculture of wastewater produced by small communities

Different parameters and quality standards among EU countries

Monitored parameters

- **Physical and chemical:** COD (Chemical Oxygen Demand), suspended solids, nitrogen, phosphorus, pH, SAR (Sodium Adsorption Ratio), conductivity.
- **Microbiological:** Faecal Contamination Indicators (*E. coli*, *Clostridium perfingens* spores, Somatic coliphages), relevant pathogenic Protozoa (*Cryptosporidium parvum* and *Giardia lamblia*) and *Salmonella*.

Process evaluation

Analysis of physical and chemical parameters:

- Feed Wastewater (influent)
- SBBGR effluent

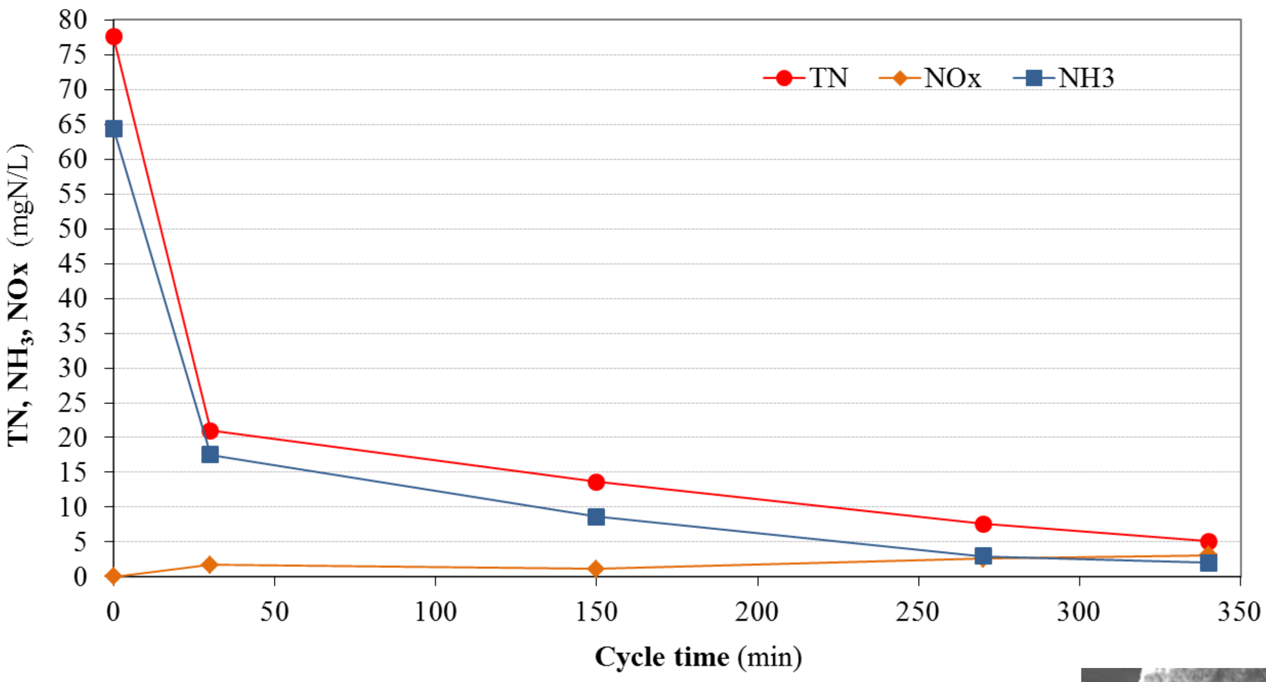
Analysis of microbiological parameters:

- Feed Wastewater (influent)
- SBBGR effluent
- SBBGR + Sand filter effluent

Physical and chemical parameters

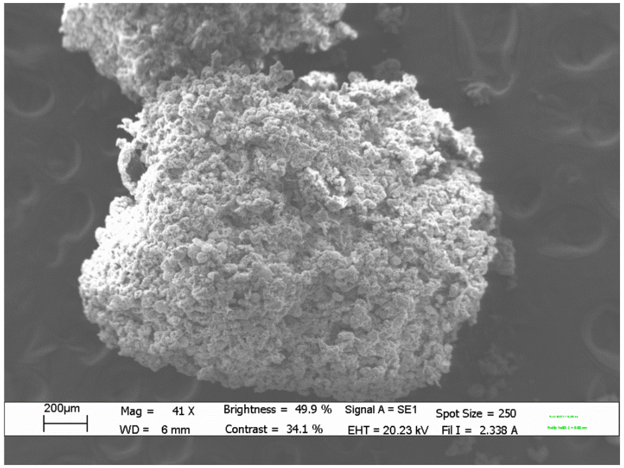
Parameter		Mean value ± standard deviation	Indicative ranges for water reuse in EU
TSS	Influent [mg/L]	**237 ± 128**	*2-60*
	Effluent [mg/L]	**10 ± 10**	
	Removal [%]	**95 ± 5**	
COD	Influent [mg/L]	**535 ± 201**	*60-100*
	Effluent [mg/L]	**38 ± 17**	
	Removal [%]	**93 ± 3**	
BOD_5	Influent [mg/L]	**321 ± 115**	*10-70*
	Effluent [mg/L]	**2 ± 2**	
	Removal [%]	**99 ± 1**	
NH_4^+	Influent [mg/L]	**52 ± 19**	
	Effluent [mg/L]	**2 ± 5**	
	Removal [%]	**96 ± 8**	
TN	Influent [mg/L]	**73 ± 26**	*10-30*
	Effluent [mg/L]	**17 ± 9**	
	Removal [%]	**77 ± 11**	
P_{tot}	Influent [mg/L]	**11 ± 5**	*1-10*
	Effluent [mg/L]	**4 ± 1**	
	Removal [%]	**62 ± 15**	

Physical and chemical parameters



Nitrogen removal during reaction phase

Nitrifying and denitrifying bacteria can coexist in different regions of granules leading to simultaneous nitrification-denitrification.



Physical and chemical parameters

Parameter		**Mean value ± standard deviation**	**Indicative ranges for water reuse in EU**
pH	Influent	**7.4 ± 0.2**	*6.0-9.5*
	Effluent	**7.8 ± 0.2**	
Conductivity	Influent [μS/cm]	**1223 ± 178**	*1000-3000*
	Effluent [μS/cm]	**892 ± 99**	
SAR	Influent	**2.5 ± 0.6**	*6-12*
	Effluent	**2.8 ± 0.8**	

Influent

SBBGR Effluent

Sand filter effluent

Bacteria

Parameter		Mean value ± standard deviation	Typical secondary effluent
E. coli	Influent [MPN/100mL]	**$1.0 \pm 2.9 \cdot 10^7$**	10^3-10^5
	Effluent [MPN/100mL]	**$0.9 \pm 2.1 \cdot 10^3$**	
	LUR	**3.2 ± 1.1**	
***Clostridium perfringens* spores**	Influent [CFU/100mL]	**$5.2 \pm 5.2 \cdot 10^5$**	10^3-10^5
	Effluent [CFU/100mL]	**$4.9 \pm 6.5 \cdot 10^4$**	
	LUR	**1.1 ± 0.4**	
Salmonella	Influent	**Present**	0-10^1
	Effluent	**Never detected**	

***WHO - reuse: E. coli < 10^3* CFU/100mL**

LUR: Log Unit Removed; **MPN:** Most Probable Number; **CFU**: Colony Forming Units.

Virus and protozoa

Parameter		Mean value ± standard deviation	Typical secondary effluent
Somatic coliphages	Influent [PFU/100mL]	**$2.8 \pm 3.3 \cdot 10^5$**	
	Effluent [PFU/100mL]	**$1.5 \pm 1.7 \cdot 10^4$**	*10^3-10^4*
	LUR	**1.4 ± 0.3**	
Giardia lamblia cysts	Influent [Cysts/L]	**$1.3 \pm 1.6 \cdot 10^3$**	
	Effluent [Cysts/L]	**$2.9 \pm 3.6 \cdot 10$**	*10^2-10^3*
	LUR	**1.5 ± 0.9**	
Cryptosporidium parvum oocysts	Influent [Oocysts/L]	**$4.7 \pm 4.7 \cdot 10^1$**	
	Effluent [Oocysts/L]	**0.7 ± 0.5**	*10^1-10^2*
	LUR	**1.8 ± 0.3**	

Conventional primary and secondary treatments are almost uneffective in protozoa removal (< 1 log unit)

LUR: Log Unit Removed; **PFU**: Plaque Forming Units

Bacteria

Parameter		Mean value ± standard deviation
E. coli	Effluent [MPN/100mL]	**$6.0 \pm 9.1 \cdot 10$**
	LUR	**1.0 ± 0.7**
***Clostridium perfringens* spores**	Effluent [CFU/100mL]	**$1.8 \pm 2.1 \cdot 10^3$**
	LUR	**1.6 ± 0.7**
Salmonella	Effluent	**Never detected**

SBBGR + Sand filter

4.2 log units

2.7 log units

Maximum *E. coli* concentration for unrestricted and restricted irrigation

France: 250 - 10000 CFU/100mL

Spain: 100 - 1000 CFU/100mL

Germany: 0 - 200 CFU/100mL

LUR: Log Unit Removed; **MPN:** Most Probable Number; **CFU**: Colony Forming Units.

Virus and protozoa

Parameter		Mean value ± standard deviation
Somatic coliphages	Effluent [PFU/100mL]	**$2.9 \pm 4.7 \cdot 10^2$**
	LUR	**1.8 ± 0.4**
Giardia lamblia cysts	Effluent [Cysts/L]	**0.7± 0.7**
	LUR	**1.4 ± 0.6**
Cryptosporidium parvum oocysts	Effluent [Oocysts/L]	**Never detected**

SBBGR + Sand filter

3.2 log units

2.9 log units

> 2 log units

LUR: Log Unit Removed

DISINFECTION

Parameter	Feed wastewater	SBBGR	SBBGR + Sand filter
E. coli [MPN/100mL]	$1.0 \pm 2.9 \cdot 10^7$	$0.9 \pm 2.1 \cdot 10^3$	$6.0 \pm 9.1 \cdot 10$
Clostridium perfringens spores [CFU/100mL]	$5.2 \pm 5.2 \cdot 10^5$	$4.9 \pm 6.5 \cdot 10^4$	$1.8 \pm 2.1 \cdot 10^3$
Salmonella	Present	Never detected	Never detected
Somatic coliphages [PFU/100mL]	$2.8 \pm 3.3 \cdot 10^5$	$1.5 \pm 1.7 \cdot 10^4$	$2.9 \pm 4.7 \cdot 10^2$
Giardia lamblia cysts [Cysts/L]	$1.3 \pm 1.6 \cdot 10^3$	$2.9 \pm 3.6 \cdot 10$	0.7 ± 0.7
Cryptosporidium parvum oocysts [Oocysts/L]	$4.7 \pm 4.7 \cdot 10^1$	0.7 ± 0.5	Never detected

CONCLUSIONS

- Physical and chemical quality of SBBGR effluent are compatible with agricultural reuse.
- Microbiological quality of SSBGR effluent is higher or comparable to that obtained at conventional WWTPs by primary and secondary treatments.
- The average *E. coli* content in the effluent of SBBGR would allow its reuse according to WHO criteria.
- The integration of SBBGR with sand filter increased microbiological quality of the effluent for all the monitored parameters (1.0-1.8 log units) and the plant effluent met quality criteria of several countries.
- SBBGR + sand filter reduced protozoa concentration to less than 1 cysts/L.
- Tertiary disinfection by UV (fluency 40 mJ/cm^2) reduced the *E. coli* and virus content below 10 MPN/100mL and PFU/100mL respectively.
- Tertiary disinfection by PAA (1 mg/L) completely removed *E. coli*.

THANK YOU FOR YOUR ATTENTION