At Moscow WWTPs (Kuryanovsky and Luberetsky) ,each having water capacity of 2,5 mln m3/day, all mixture of primary and secondary sludge is digested at 53 ^{0}C with SRT=HRT 7 days. The volatile solid reduction (VSR) is about 43-46% and gas production is about 0.33 m3/kg VS fed. In order to increase VSR and gas production many different optimization variants were studied. One of them was examining of usltrasonic (US) treatment of waste activated sludge (WAS) (or surplus sludge) before digesters. We considered several leading suppliers of US technology working with sludge treatment for purchasing pilot machine to test the technology. In the end Weber Entec was chosen as it proposed the most suitable conditions. The ultrasonic machine Smart DMS suited our requirements most of all, had the most attractive price and, what is not of the least importance, technical and management assistance was the most efficient and helpful. All operations (delivery, turnkey) were done according to the schedule and without mistakes.

The train of experiments was the following. The US machine was installed near the pipe with thickened WAS feeding digesters and connected to it by bypass pipe through a 1m^{3} tank (Figure 1). It was possible to sample the origin incoming WAS before the machine and WAS ultrasonically treated at the outlet of the machine. 3-4 samples of WAS influent and effluent in parallel were collected during 1,5 hour of continuous working every day, averaged, and then delivered to laboratory digesters as feeding substrate. Lab digesters worked in parallel lines as a control fed by untreated WAS and experimental fed by US treated WAS.

Рисунок 1. The ultrasonic machine in the process of installation.

As there was no possibility to check the effect of US directly at a full- scale digester because all WAS and primary sludge was collected and mixed in one tank and then distributed among all 24 digesters, so we had to use lab digesters. Probably this fact affected the results badly as treated samples of WAS were exposed to air for an hour before were fed to lab digesters.

Before conducting continuous digestion with every day feeding and discharging, several series of experiments in batch reactors (biogas methane potential tests) were conducted to check the influence of:

1. specific ultrasound power on gas volume;
2. the influence of recycle pump flow rate on on gas volume.

In the range of specific energy from 1 to 8.5 kWh/m3 of WAS no prominent correlation was noticed (N=20).

Recycling pump rate stated by pump engine frequency from 0 to 45 Hz increased produced gas volume (Figure 2).

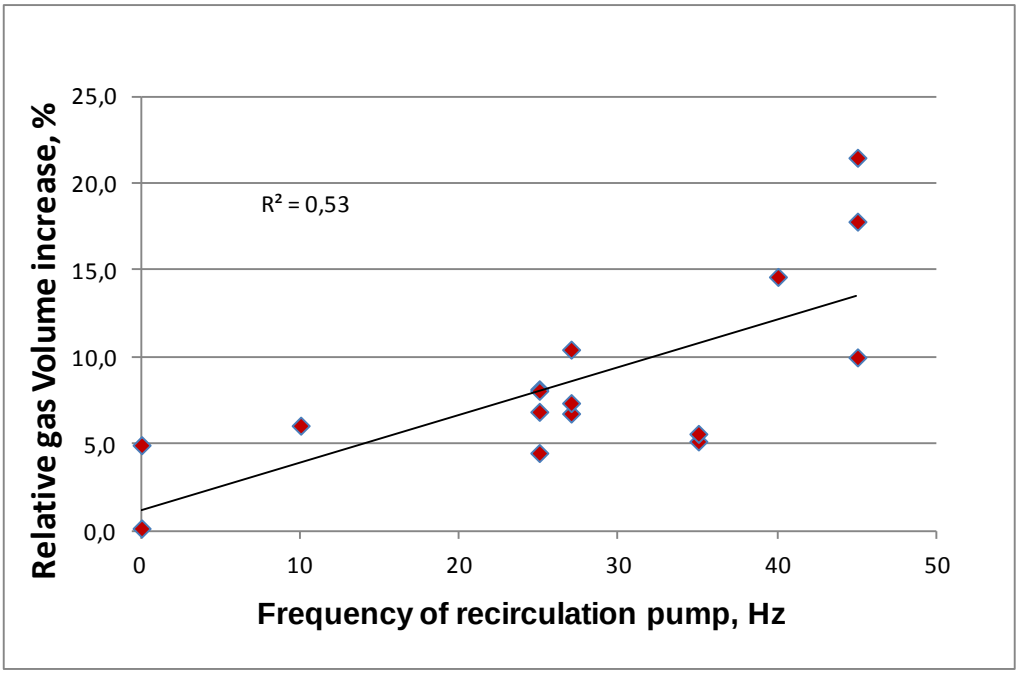

Figure 2. The influence of recycle pump of Weber Entec usltrasonic machine rate on gas production improvement.

Moreover, preliminary experiments for comparing digestion of WAS, 100% US treated, with digestion of mixture of 60% untreated origin WAS and only 40% US treated, showed that 60/40 mixture gave even higher gas production than fully treated sludge.

So the basic data for continuous digestion of ultrasonic sludge were chosen

- specific energy of 2.2-2.5 kWh/m3 as recommended by Weber Entec,
- 45 Hz of recycling pump that was equal to recycle pump/ main pump flow ratio = 8.4
- 40 % of US treated sludge in digester feeding.

Digestion was conducted in 1 L bottles in 3 replicants each variant, under conditions similar to full-scale digesters - HRT = 7 days, T = 53 ^{0}C, in thermostat (Figure 3). The bottles were periodically fully mixed, feeding and discharging were made once a day approximately one hour

since US treatment. Gas volume was calculated from pressure which was measured daily before feeding by manometer with a needle through a rubber seal.

Figure 3. Laboratory digesters in thermostat.

Both WAS and digested sludge were analyzed for TS, VS, COD, pH. TS_{sol}, VS_{sol}, COD_{sol} in centrifugate liquid of WAS control and WAS US treated were analyzed as well. N-NH4, P-POP4 were measured in liquid phase of digested sludge.

At Kuryanovsky WWTP where the experiments were conducted only COD removal and nitrification are realized. The properties of WAS are listed in Table 1.

Table 1 Properties of waste activated sludge (age 10 days) (average meanings).

	W, %	Z, %	TS, g/L	VS, g/L	COD, g/L
WAS summer 2013	97,3	33,7	27	18	26

In spite of batch BMP tests showed no influence of exposed specific power of US it was decided to check it at continuous digestion experiments. To increase the power from 2.5 kWh/m^3 to 5 kWh/m^3 WAS treated twice under the same conditions (it was collected in 1 m3 tank and then treated again). So 3 digestion lines were conducted – control WAS, treated under 2.5 kWh/m^3 and under 5 kWh/m^3. The main parameters of digestion are shown below. (Figure 4, Figure 5, Table 2)

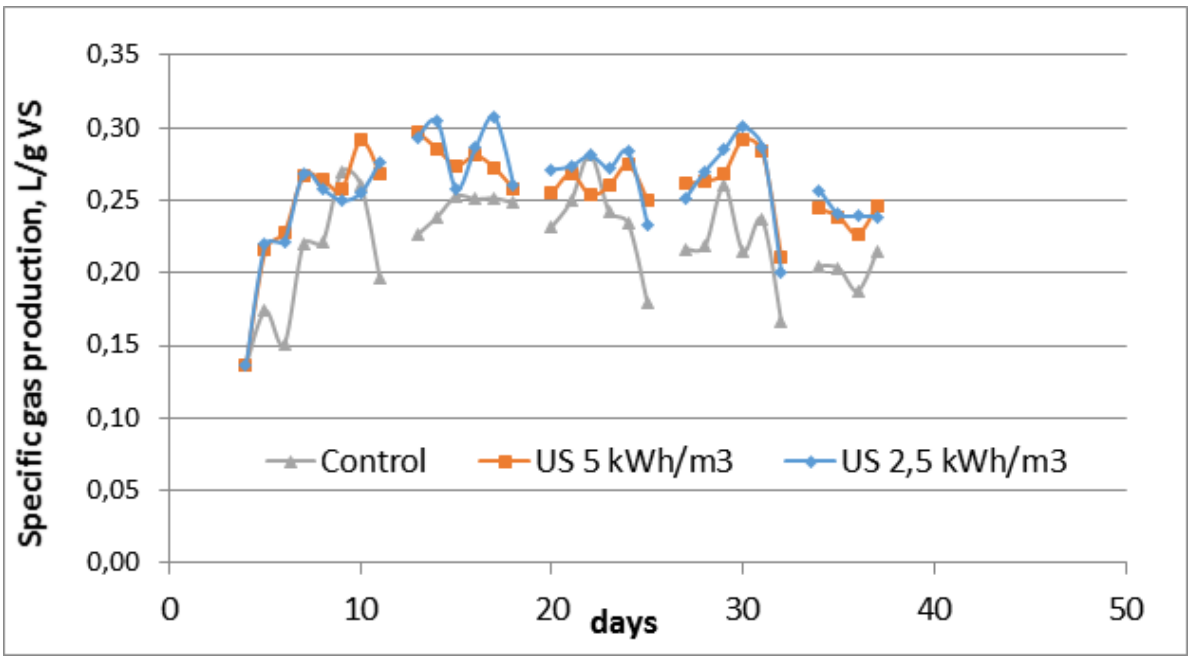

Figure 4. Specific gas production during digestion of WAS in continuous experiment**.**

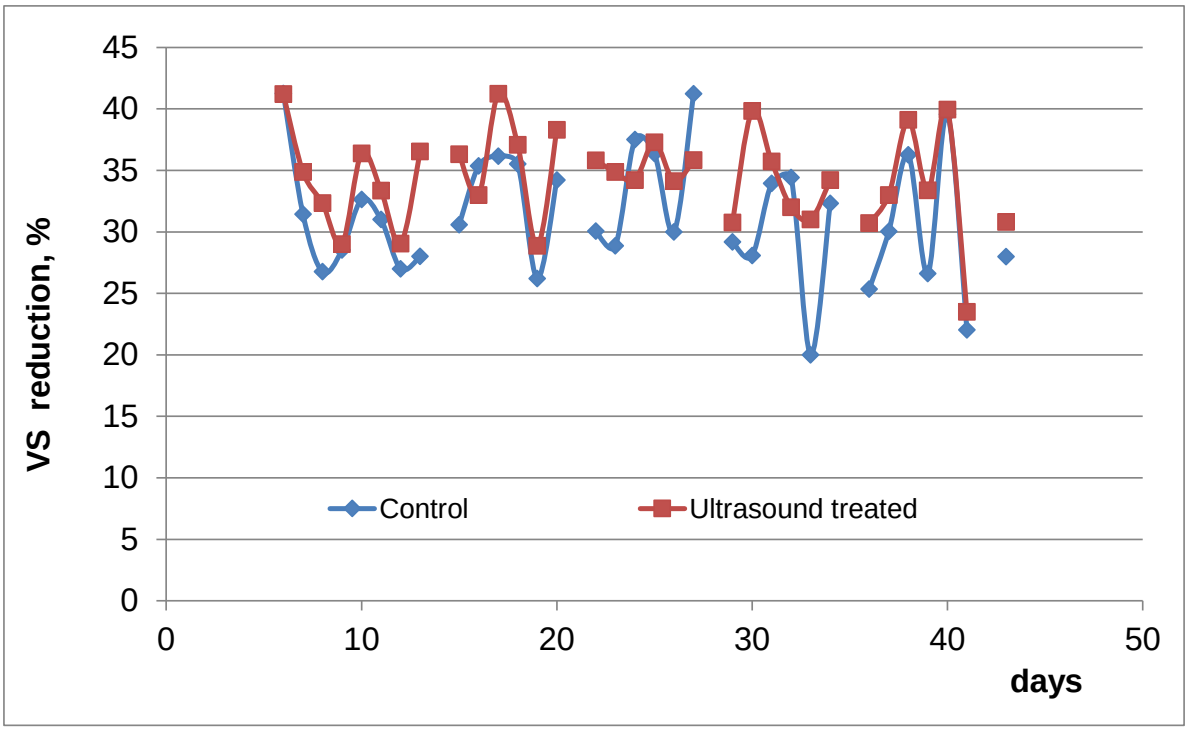

Figure 5. Volatile solids reduction during digestion of WAS (US treated at 2.5 kWh/m^3) in continuous experiment.

As shown again there is no prominent influence of enhanced ultrasonic power on gas production increase as the effect for 2.5 kWh/m^3 and 5 kWh/m^3 was the same – about 17% comparing with control. The nature if ultrasonic effect on activated sludge is homogenization, thereby increasing of reactive surface and enzymatic release. This effect likely is the same in the range of 1-10 kWh/m^3. Cell disruption begins from much higher (x10 or even x100) energies that's why no prominent effect of energy increase in this economically reasonable range was observed.

Volatile solids reduction was about 10% higher for US treated sludge than for control untreated sludge. The disparity between efficiency rates of gas yield and VS reduction can be explained by the less specific gas yield of recalcitrant organic substances and it could be observed often in digestion experiments.

Table 2. The main digestion parameters.

	VSR, %	Specific gas production, L/g VS
Control WAS	31,4	0,22
2 kWh/m3 US treated WAS	34,5	0,26
Improvement, %	9,9	17,2

The liquid phase of digested sludge was characterized by moderate increase of ammonium concentrations that conforms with higher organic decomposition (Table 3).

Table 3. Liquid phase properties of digested WAS treated under different specific energy.

	N-NH4	P-PO4
Control WAS	587	89
2.5 kWh/m3 US treated WAS	656	90
5 kWh/m3 US treated WAS	635	84

Conclusions

The study of the effect of surplus sludge ultrasonic treatment at Weber Entec Smart DMS on digestion was conducted in JSC “Mosvodokanal”, Moscow. The results showed that the ultrasonic treatment of 40% of WAS at 2.2-2.5 kWh/m3 energy increased gas yield up to 17% and volatile solids reduction by 10% during the following digestion in laboratory reactors. Up to the moment calculated economical benefits and 2-3 years payback make this technology attractive and worth for further consideration for implementation.