

Investigation on inactivation of microbial indicators and urea decomposition of human urine by thermal storage

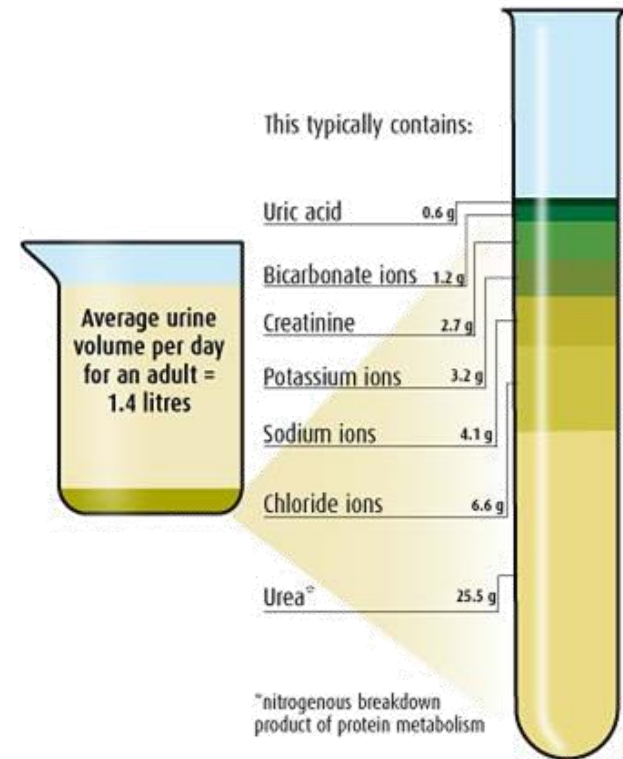
Zifu Li, Yajie Li, Xiaoqin Zhou

Centre for sustainable environmental sanitation
University of Science and Technology Beijing



Human urine is a kind of resource

0.05% Ammonia	0.6% Potassium
0.18% Sulphate	0.1% Sodium
0.12% Phosphate	0.1% Creatinine
0.6% Chloride	0.03% Uric acid
0.01% Magnesium	2% urea
0.015% Calcium	95% water



● Nitrogen (ammonia/ urea)

● Phosphorus

● Energy

● Reclaimed Water

MPA

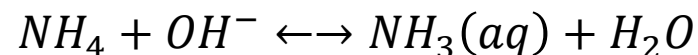
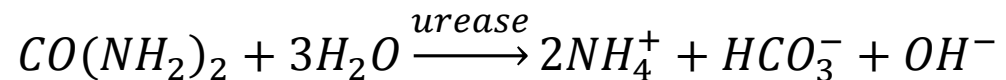
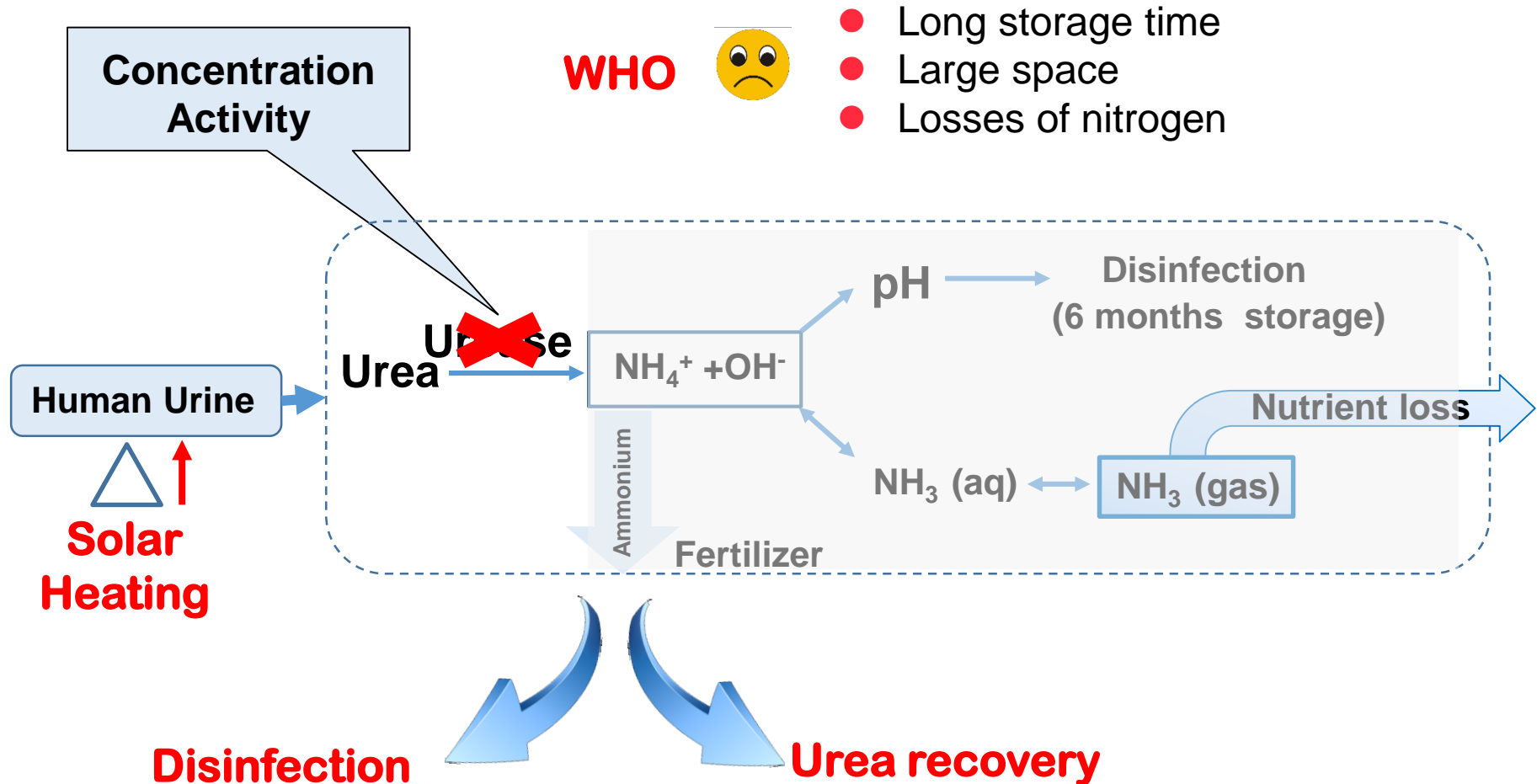
Storage

Forward osmosis

MFC-MEC

Air stripping

Storage offers the most simple way for urine treatment in terms of agricultural use, especially for rural area



➤ Experimental set-up

- Scenarios 1: diluted urine (2:1)
- Scenarios 2: diluted urine and undiluted urine
- Scenarios 3: repeatable experiment with diluted urine and undiluted urine

➤ **60 °C, 70 °C, Control (ambient temperature)**

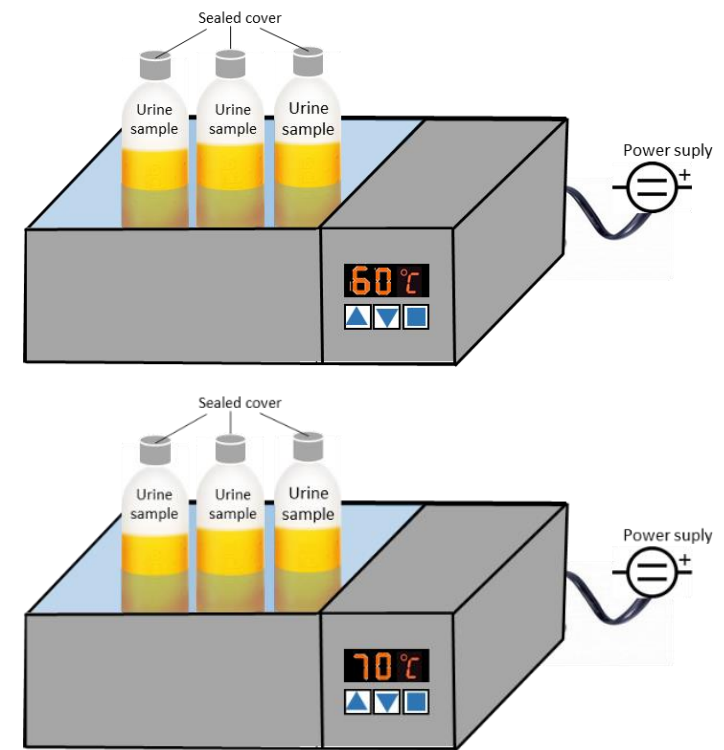


Table 1 Main characteristics of fresh urine collected for the experiments

Sampling	pH	Ammonia/ammonium (mg/L)	Fecal coliforms (CFU/L)	E. Coli (CFU/L)
1	7.15	292.49	1.4×10^6	2.0×10^4
2	6.84	501.52	4.5×10^4	-
3	6.80	490.66	4.2×10^3	3.2×10^3

Note: “-” means not detected.

- Chemical analysis: pH, ammonia/ammonium
- Microbial analysis: Fecal coliform, *E.coli*, total coliform, bacteria community structure

➤ Experimental results

Inactivation of bacteria: Fecal coliform

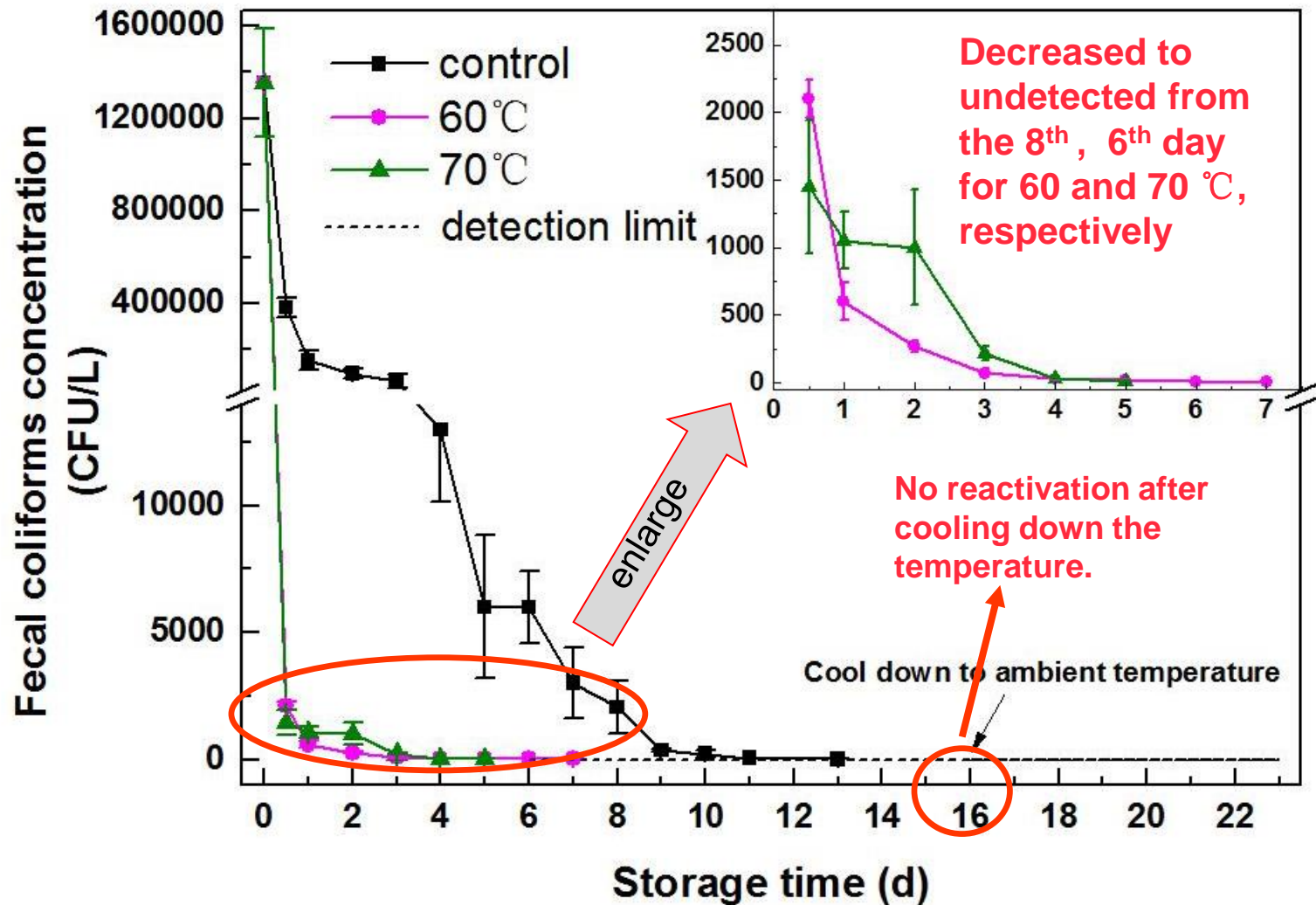
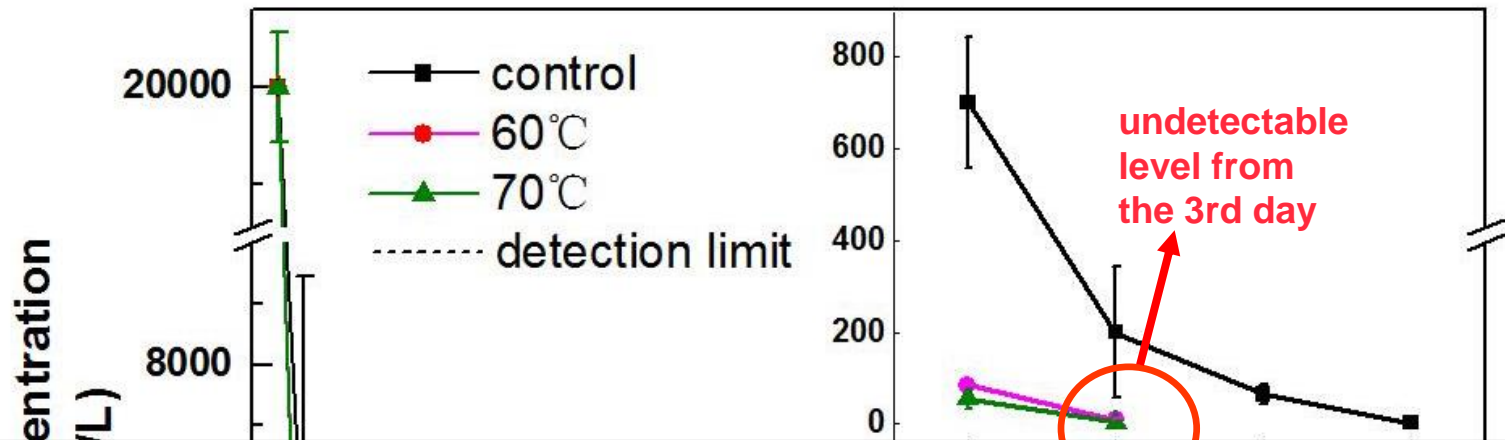


Fig. Fecal coliforms concentration in the three urine samples during storage

Urine stored at ambient temperature need 14 days to eliminate the fecal coliform.

➤ Experimental results

Inactivation of bacteria: E.coli



High temperature could speed-up the hygienization process

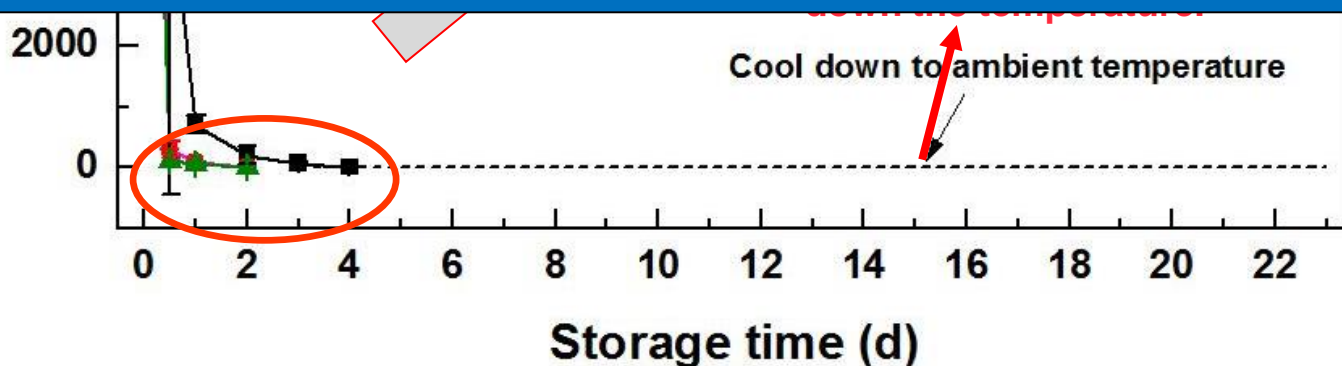


Fig. *E.coli* concentration in the three urine samples during storage

Urine stored at ambient temperature need 5 days to eliminate the E.coli.

➤ Experimental results

Urea hydrolysis

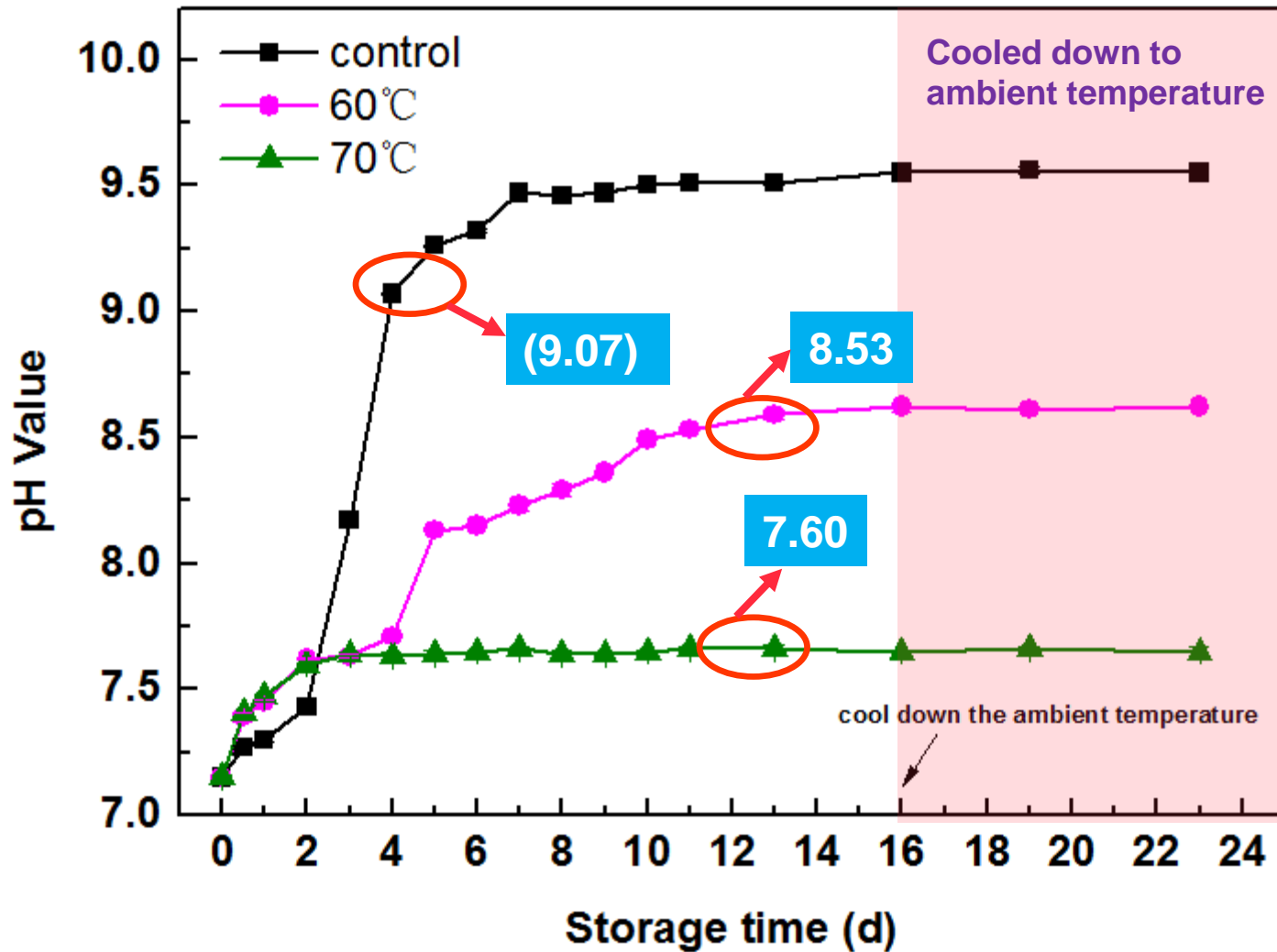


Fig. pH value in the diluted urine during the storage time

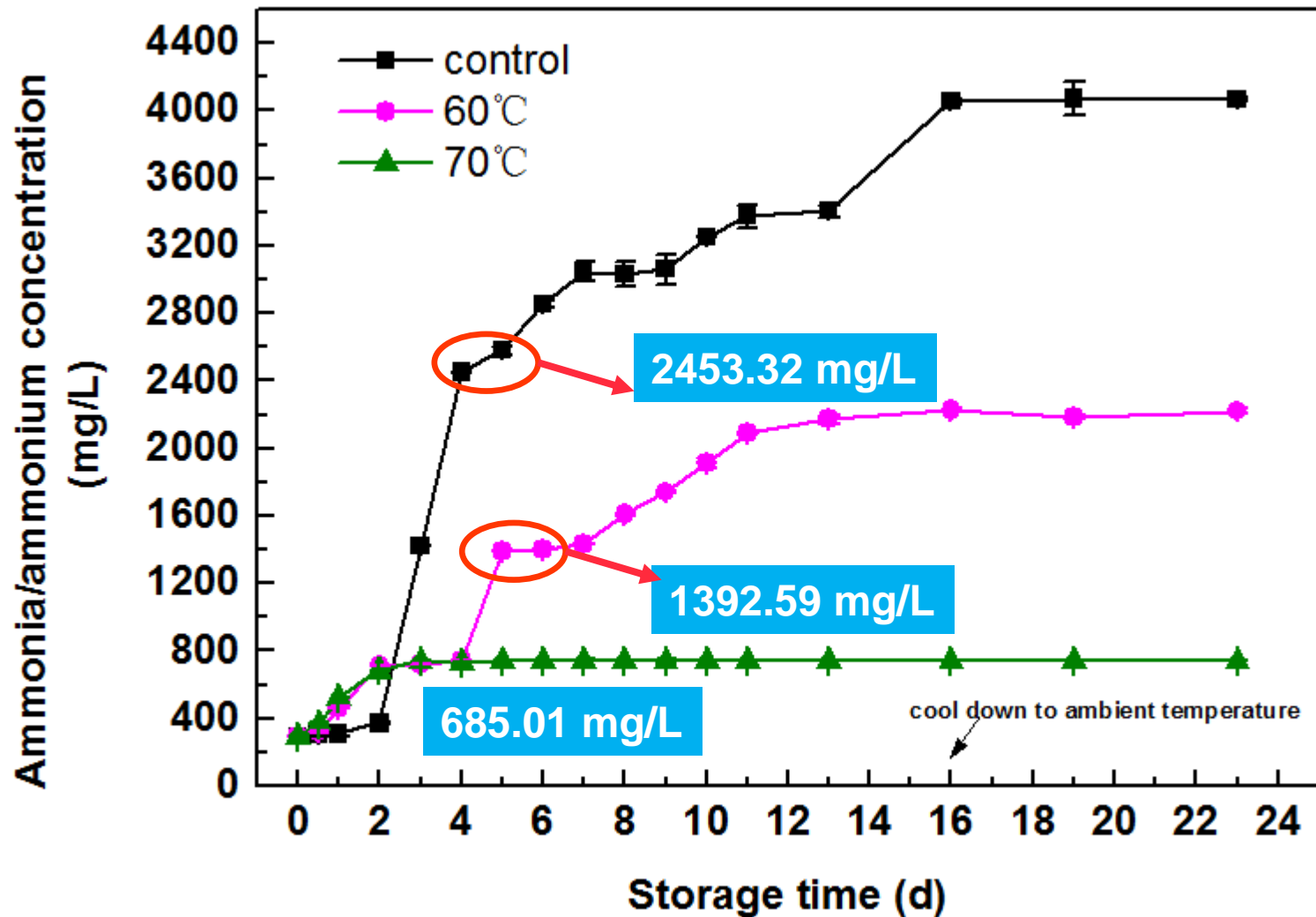


Fig. Ammonia/ammonium concentration in the diluted urine during the storage time

➤ Experimental results

Possible impact factor for urea hydrolysis

Normally, urease activity is 65°C (Hagenkamp-Korth et al., 2015)

70°C storage

Salmonella typhimurium,
Streptococcus faecalis, and *E. coli*,
could be inactivated at 65°C
(Fjendbo et al., 1998)

Inhibiting urease activity

Killing UPB(urease producing bacteria)

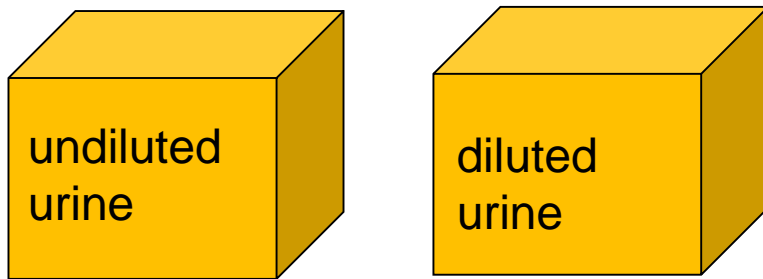


it can be hypothesized that reduction of urease concentration by inactivation of UPB contributed more to the urea hydrolysis process

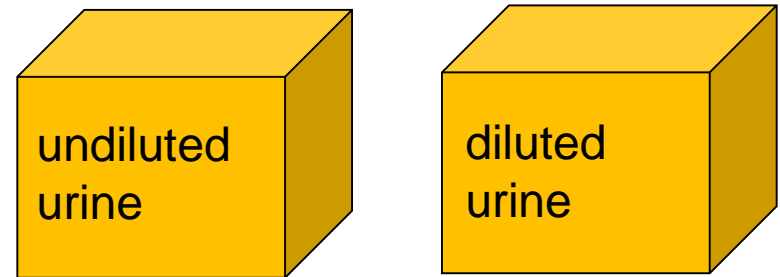
Considering both disinfection and urea hydrolysis effects, the thermal storage of source-separated urines at 70°C for 7 days could realize pathogenic bacteria inactivation and urea stabilization.

Thermal treatment efficiency of undiluted and diluted urine storage

Scenarios 2 & 3



Urine stored at 70°C for 7 days



cooled down to ambient temperature for another 7 days monitoring in order to check the sustainable stabilization effect after thermal storage.

➤ Experimental results

▶ Bacteria inactivation and stabilization

Thermal treatment efficiency of undiluted and diluted urine storage

- Fecal coliforms and *E.coli* achieved totally inactivation within 2 days

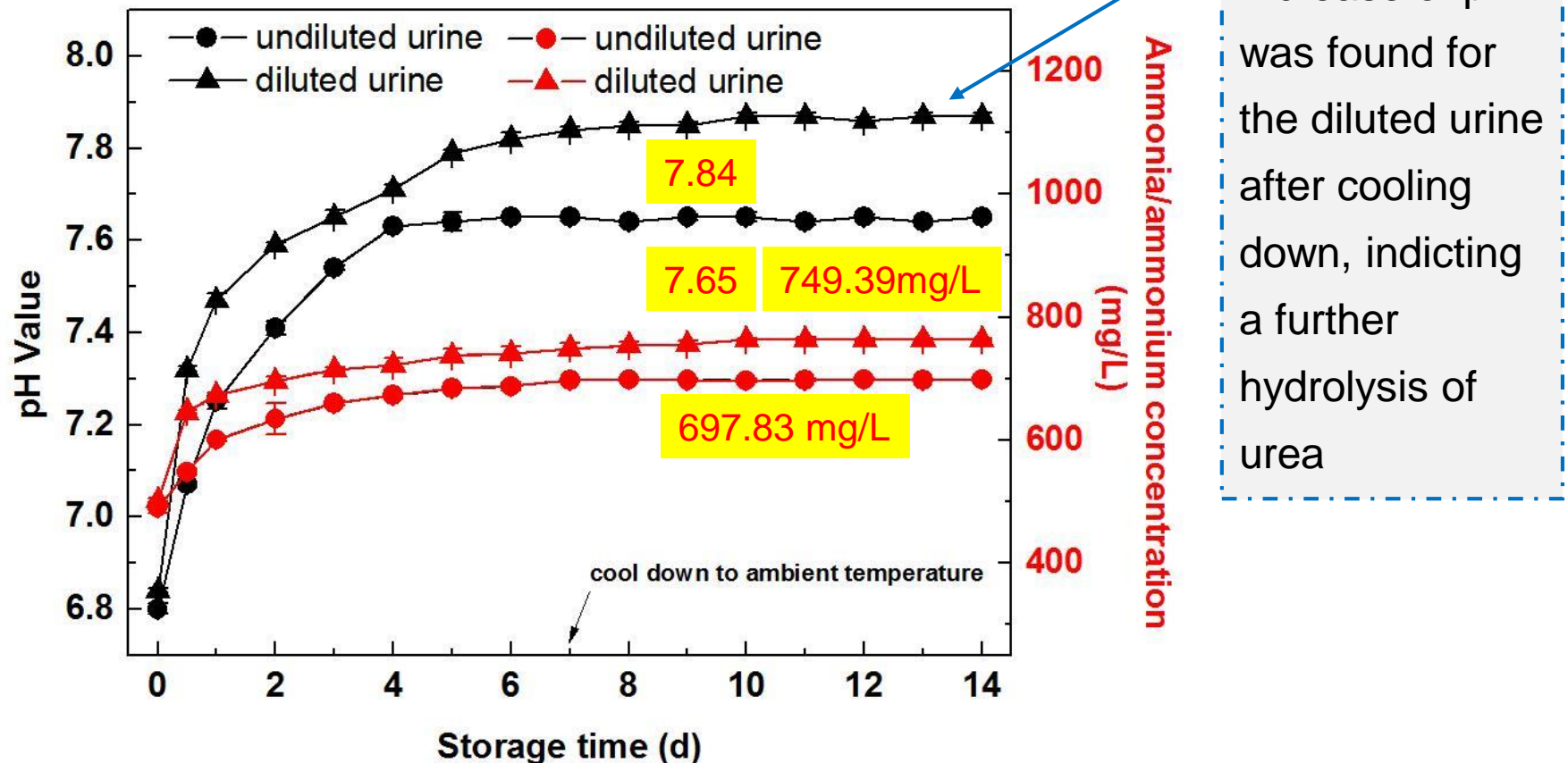


Fig. pH Value & ammonia concentration in diluted & undiluted urine

Although thermal treatment is effective for both diluted urine and undiluted urine in terms of disinfection, the **urea hydrolysis for the** diluted urine performed to be unsatisfied.

- Besides, extra heating and tank volume are required for the storage. As a consequence, **taking consideration of system stability as well as energy consumption, thermal storage is much more suitable for undiluted urine storage (source-separated dry toilet/ waterless urinal).**

➤ Experimental results

high-throughput sequencing analysis

▶ Pathogenic communities in the urine

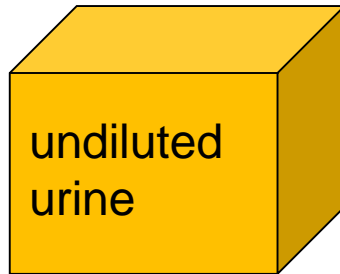
- *Campylobacter*, *Corynebacterium*, *Escherichia*, *Shigella*, *Pseudomonas* and *Stenotrophomonas* performed obviously decrease after thermal storage
- Therefore, the thermal effect caused by high temperature for urine storage was effective disinfection method for most of the pathogen bacteria.

Table. Numbers of sequences assigned to pathogenic genera in reclaimed water samples

No.	Pathogenic genus	Fresh collected urine		Sample taken at day 7	
		No. of sequences	proportion	No. of sequences	proportion
1	<i>Arcobacter</i>	2	0.02	14	0.08
2	<i>Bacillus</i>	503	5.48	2587	13.92
3	<i>Brevundimonas</i>	2956	32.22	10789	58.05
4	<i>Burkholderia</i>	0	0.00	6	0.03
5	<i>Campylobacter</i>	22	0.24	3	0.02
6	<i>Chlamydia</i>	1	0.01	14	0.08
7	<i>Chlamydophila</i>	1	0.01	14	0.08
8	<i>Clostridium</i>	49	0.53	319	1.72
9	<i>Corynebacterium</i>	2091	22.79	413	2.22
10	<i>Enterobacter</i>	0	0.00	0	0.00
11	<i>Enterococcus</i>	338	3.68	1764	9.49
12	<i>Escherichia</i> , <i>Shigella</i>	414	4.51	46	0.25
13	<i>Haemophilus</i>	236	2.57	333	1.79
14	<i>Klebsiella</i>	0	0.00	1	0.01
15	<i>Legionella</i>	1	0.01	1	0.01
16	<i>Mycobacterium</i>	62	0.68	142	0.76
17	<i>Mycoplasma</i>	5	0.05	10	0.05
18	<i>Neisseria</i>	321	3.50	438	2.36
19	<i>Pseudomonas</i>	1314	14.32	391	2.10
20	<i>Serratia</i>	4	0.04	21	0.11
21	<i>Staphylococcus</i>	52	0.57	51	0.27
22	<i>Stenotrophomonas</i>	46	0.50	19	0.10
23	<i>Streptococcus</i>	757	8.25	1209	6.51
24	Sum	9175	10.26	18585	10.42

➤ Experimental results

Thermal treatment efficiency of undiluted and diluted urine storage



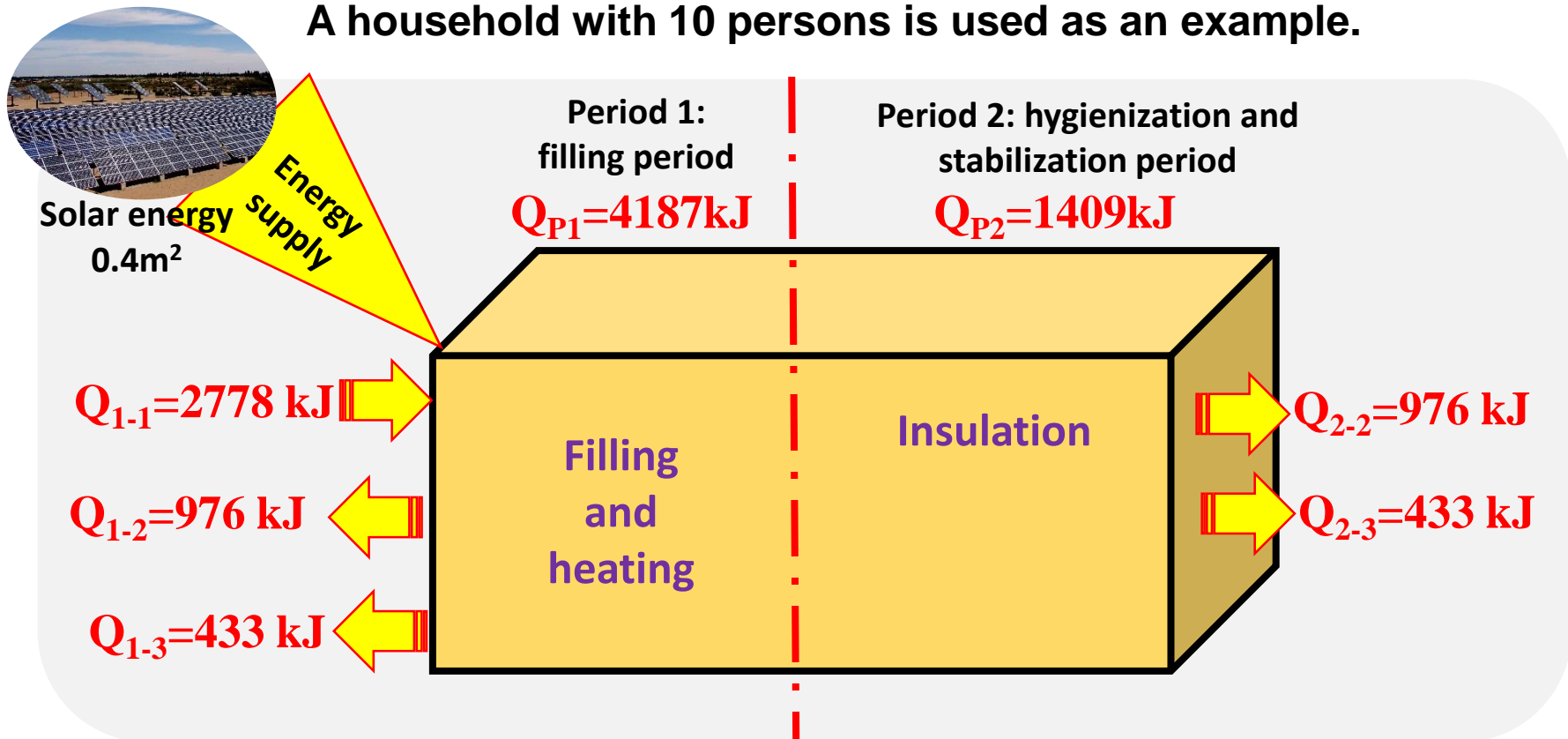
Urine stored at 70°C for 7 days

Urea recovery: directly

Agriculture use: cool down to ambient temperature and stored for use, including empty period(7 days is suggested)

Energy balance analysis

A household with 10 persons is used as an example.



- First,(filling period) for 7 days to fill up the tank;
- second, the collected urine was stored for 7 days at 70°C
- thirdly, another 7 days is suggested for the heated urine to cool to ambient temperature and stored prior to use

Non-flushing urine: $0.5\text{m} * 0.5\text{m} * 0.5\text{m}$

Conclusions

- The thermal storage of source-separated urines at 70°C for 7 days could realize both pathogenic bacteria inactivation and urea stabilization.
- Thermal treatment is much more suitable for urine storage from undiluted urine in terms of system stabilization and energy consumption.
- 70 °C thermal treatment could be effective on most of the pathogenic bacteria inactivation.

THANK YOU !

Centre for Sustainable Environmental Sanitation



010-62334378



zifuli@ces.ustb.edu.cn



www.susanchina.cn



No.30, Xueyuan RD, Haidian District, Beijing, China