Investigation of the Critical Parameters in the Production of Ceramic Water Filters

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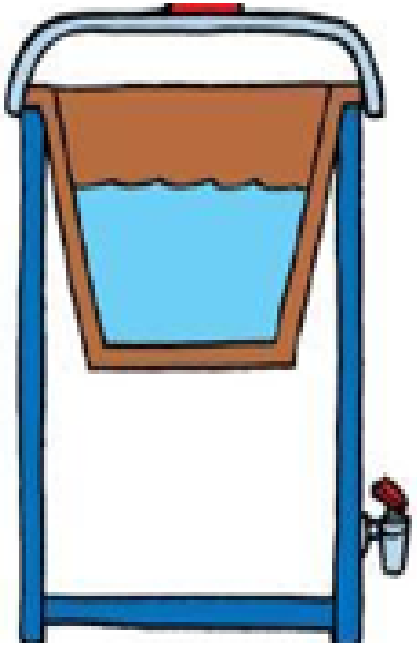

A research executed by:

RDI CAMBODIA
for a hope and a future...

engineers without borders AUSTRALIA

enbe for all

TU Delft
Technische Universiteit Delft

PRACTICA

HET WATERLABORATORIUM

kiwa
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INTRODUCTION
Research Aims & Project Scope

Project Objectives

1. To develop a better understanding of the production and use of these filters as a proven method for domestic water purification world-wide, ideally leading to an **internationally-certification process** being identified.

2. To investigate ways to **increase the flow rate** so that the ceramic water filter can cater the drinking water needs of a typical Cambodian household **without compromising the water quality and strength of the filter.**

Research Scope

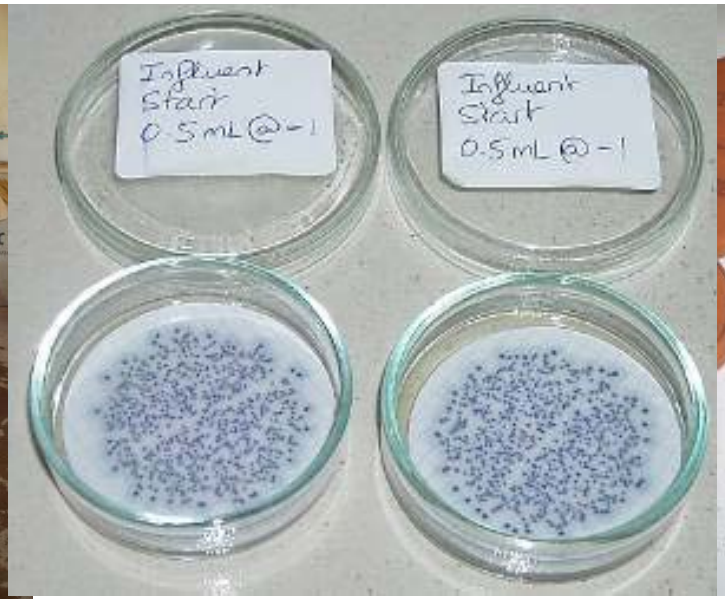
Set up and test the research production line

Test reproducibility of RDI filters by mimicking RDI processes from mixing to firing

Experiment with variations (always without silver)

1. Rice husk quantity (9.7, 11, 12, 13 and 14 kg)
2. Maximum firing temperature (685, 800, 885 and 950 deg. C.)
3. Rice husk particle size (<1 and 0.5<mm<1)

Summary of Methods



Filter Making (same as RDIC)

1. Preparation of raw materials (sieving < 1 mm)
2. Mixing of clay components (10 mins dry and 15 mins wet)
3. Forming of clay cubes for pressing
4. Pressing of clay cubes into ceramic filter form
5. Surface finishing and labeling of pressed filters
6. Drying of pressed filter elements
7. Firing and cooling in kiln

RDIC Pot composition:
mixture of clay (30 kg/batch), rice husks (9.7 kg/batch) and laterite (1 kg/batch)

Research Kiln
with temperature regulation system

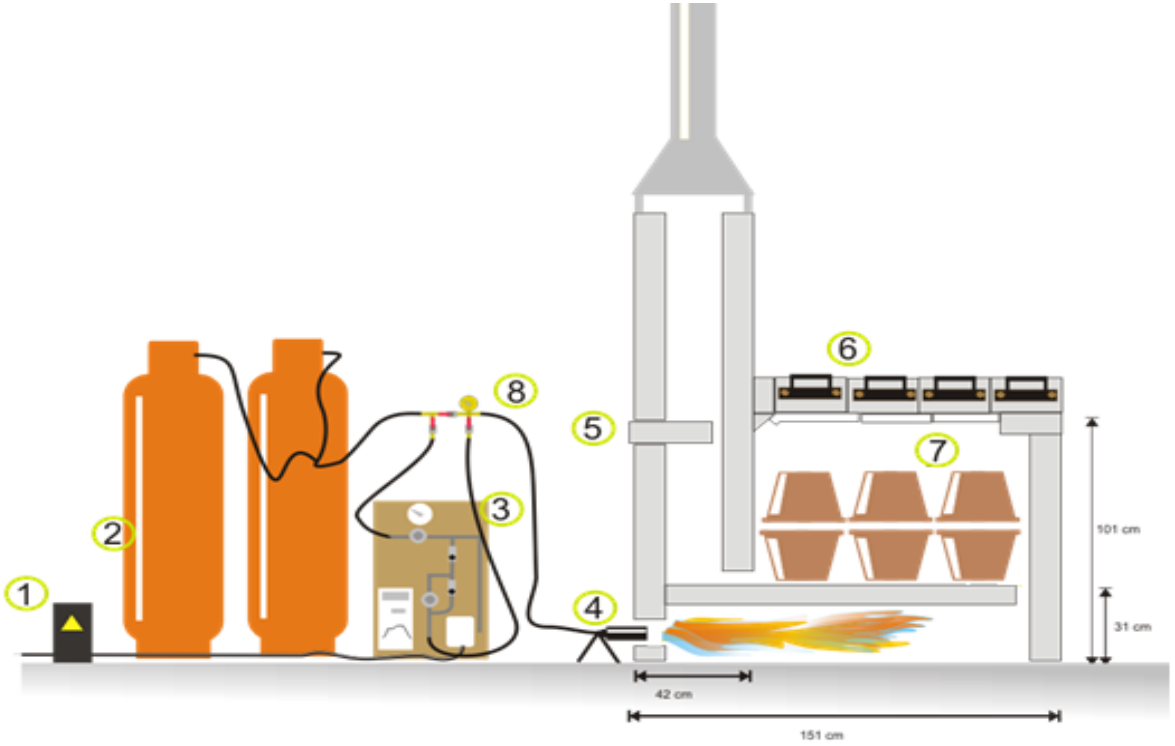


Figure 1

1. Power stabilizer
2. Gas bottles
3. Regulating system attached to wooden board
4. Burners
5. Chimney regulator
6. Roof parts
7. Internal floor.
8. Switch manual-automatic regulation.

Batch Sample Size: n=6 pots
Temperature measured at every pot (6 probes)

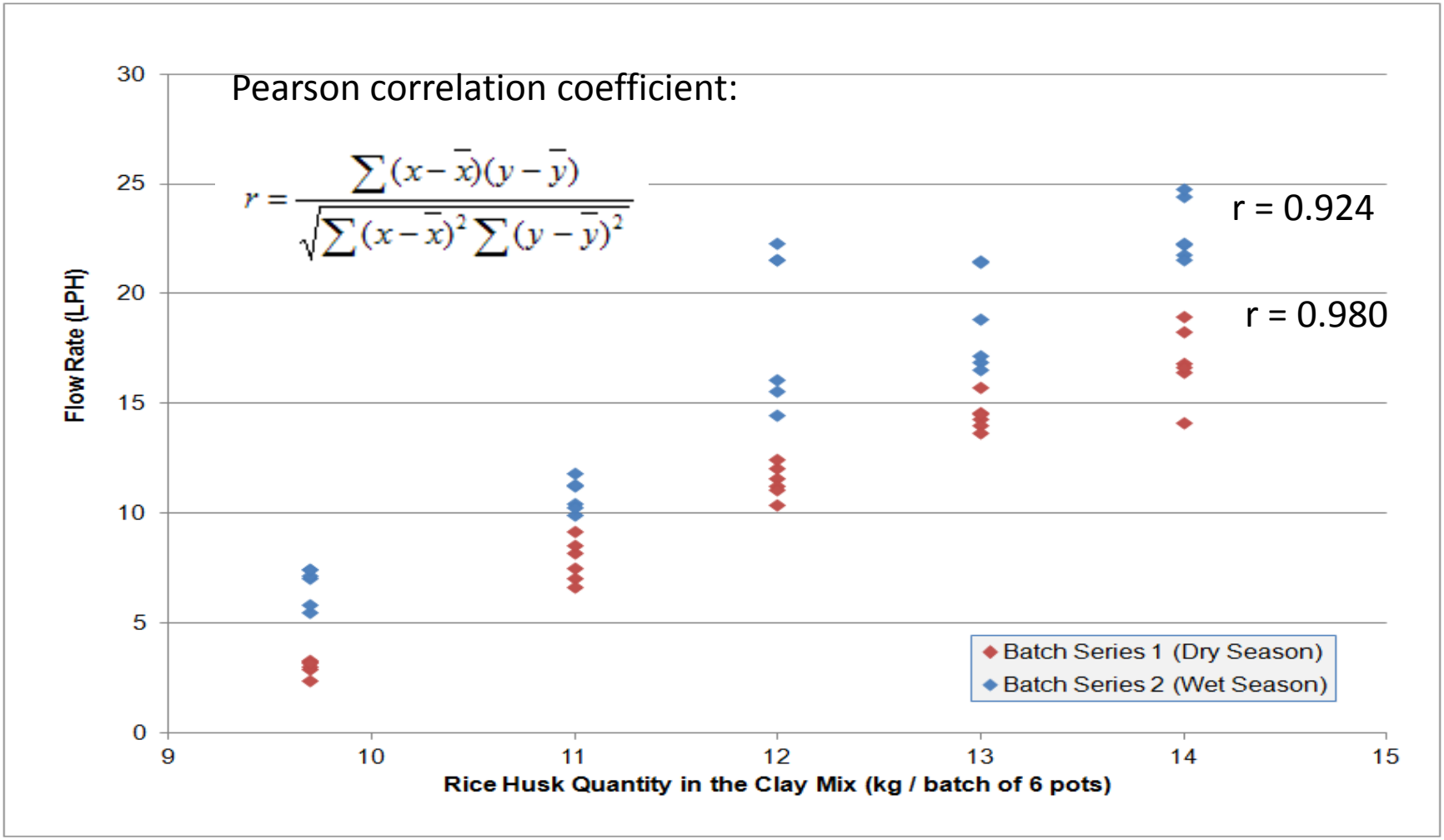
Filter Testing

- **Flow rate (at RDIC)**
  - constant water head method
  - total volume of filtered water collected from receptacle after one hour and weighed (1 L of water = 1 kg)
- **E. coli (at the RDIC Laboratory)**
  - membrane filtration method used to calculate the log-reduction value (LRV)
  - indicator of bacteria (fecal contamination)
  - strain B used (non-pathogenic E. coli) (safety first!)
  - Influent water (8 L/pot) spiked with high concentrations of E. coli: 10^3 cfu/ml without silver and 10^6 cfu/ml with silver
- **Strength** (done by GERES, Cambodia)
  - discs cut from bottom of filters
  - modulus of rupture (MOR)
- **Pore size** (done at TU Delft, Holland)
  - mercury intrusion porosimetry

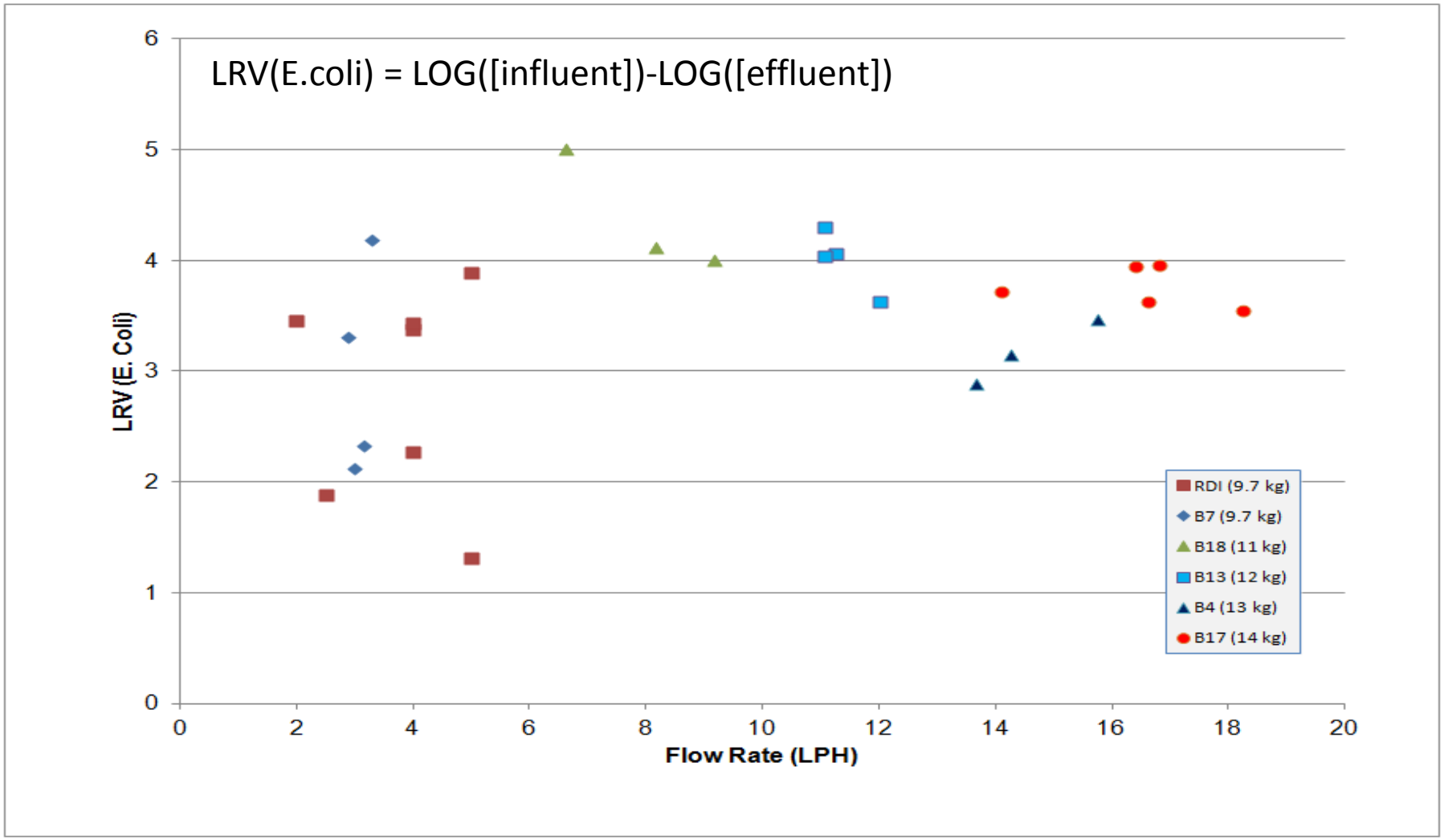
RESULTS
Rice Husk Quantity Variations

Results – Rice Husk Quantity Variations
First and Second Batch Series (Without Silver)

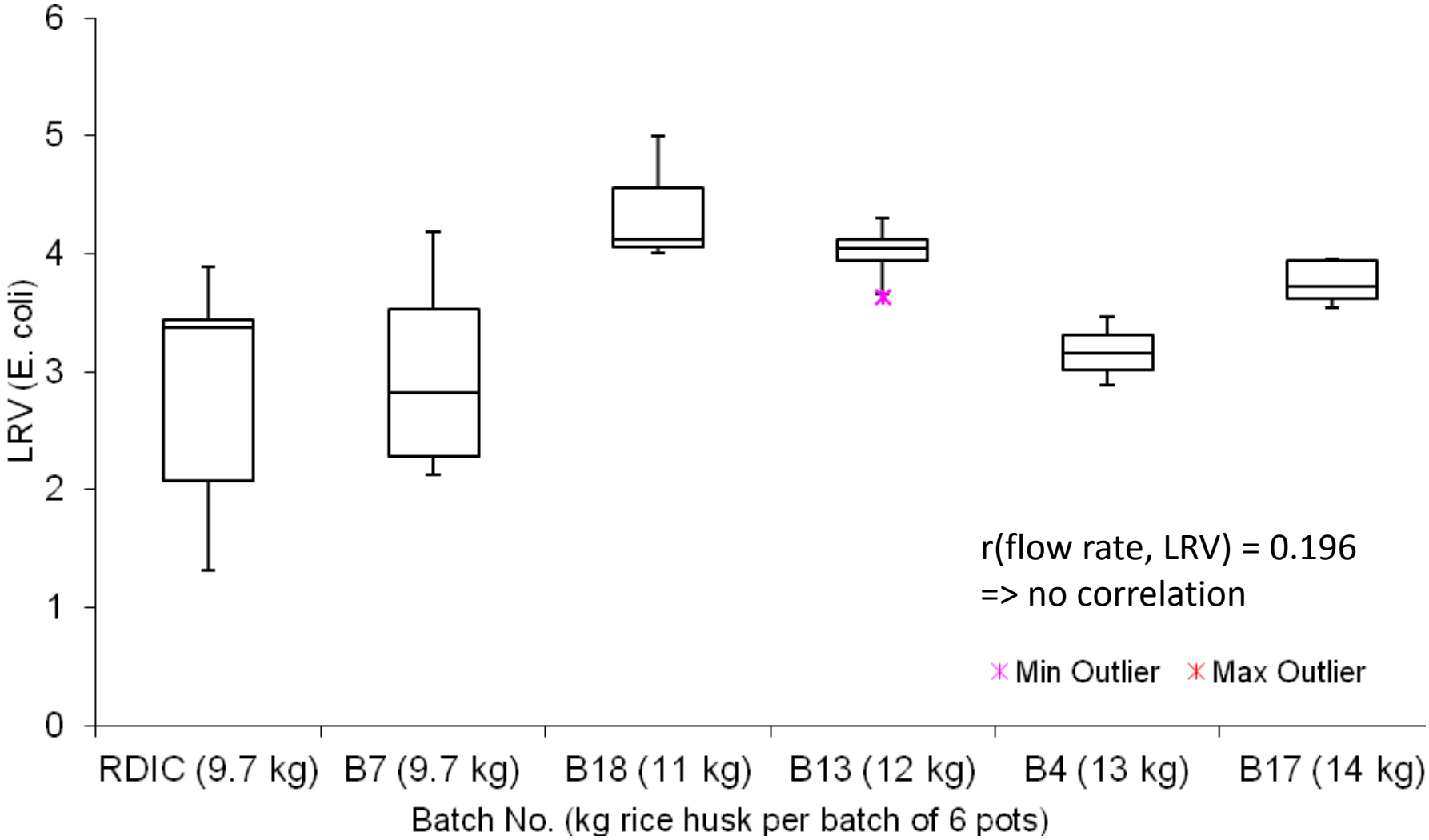
Flow rate is linearly related to rice husk quantity



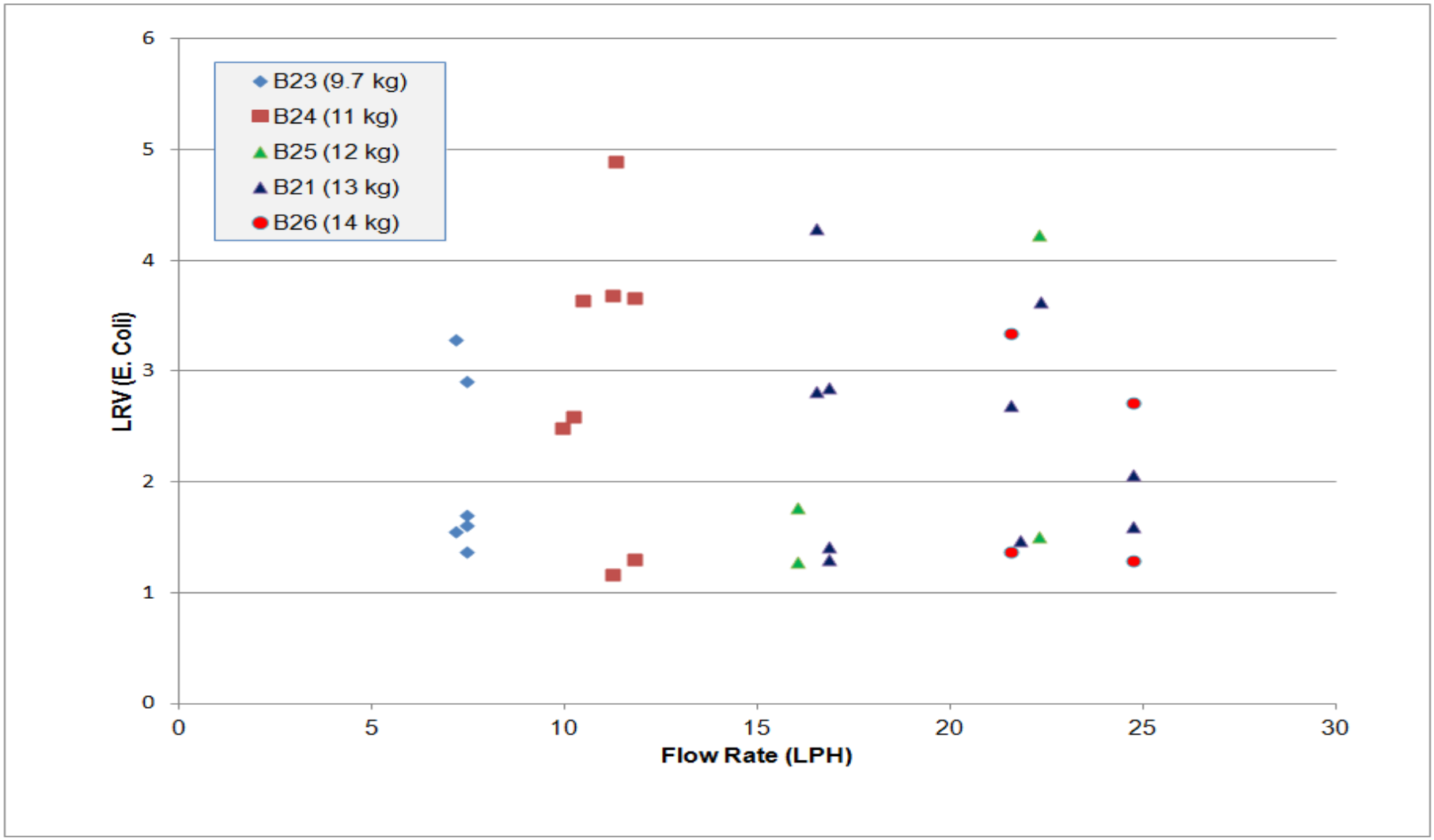
Results – Rice Husk Quantity Variations
First Batch Series (Without Silver)
LRVs (E. coli) versus Flow Rates



Results – Rice husk quantity variations
First Batch Series
Box-and-whisker plots

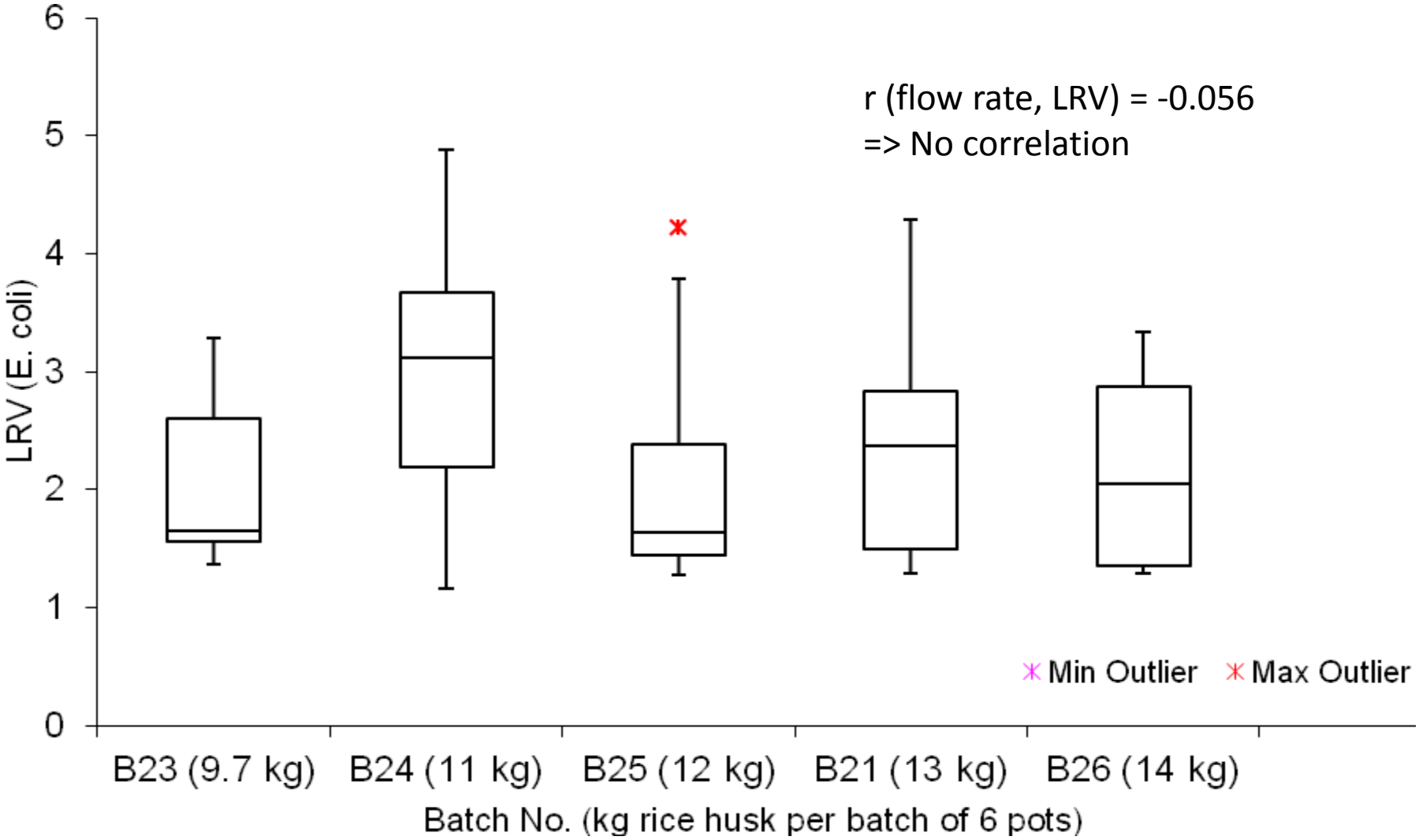


Results – Rice husk quantity variations
Second Batch Series (Without Silver)
LRVs (E. coli) versus Flow Rates

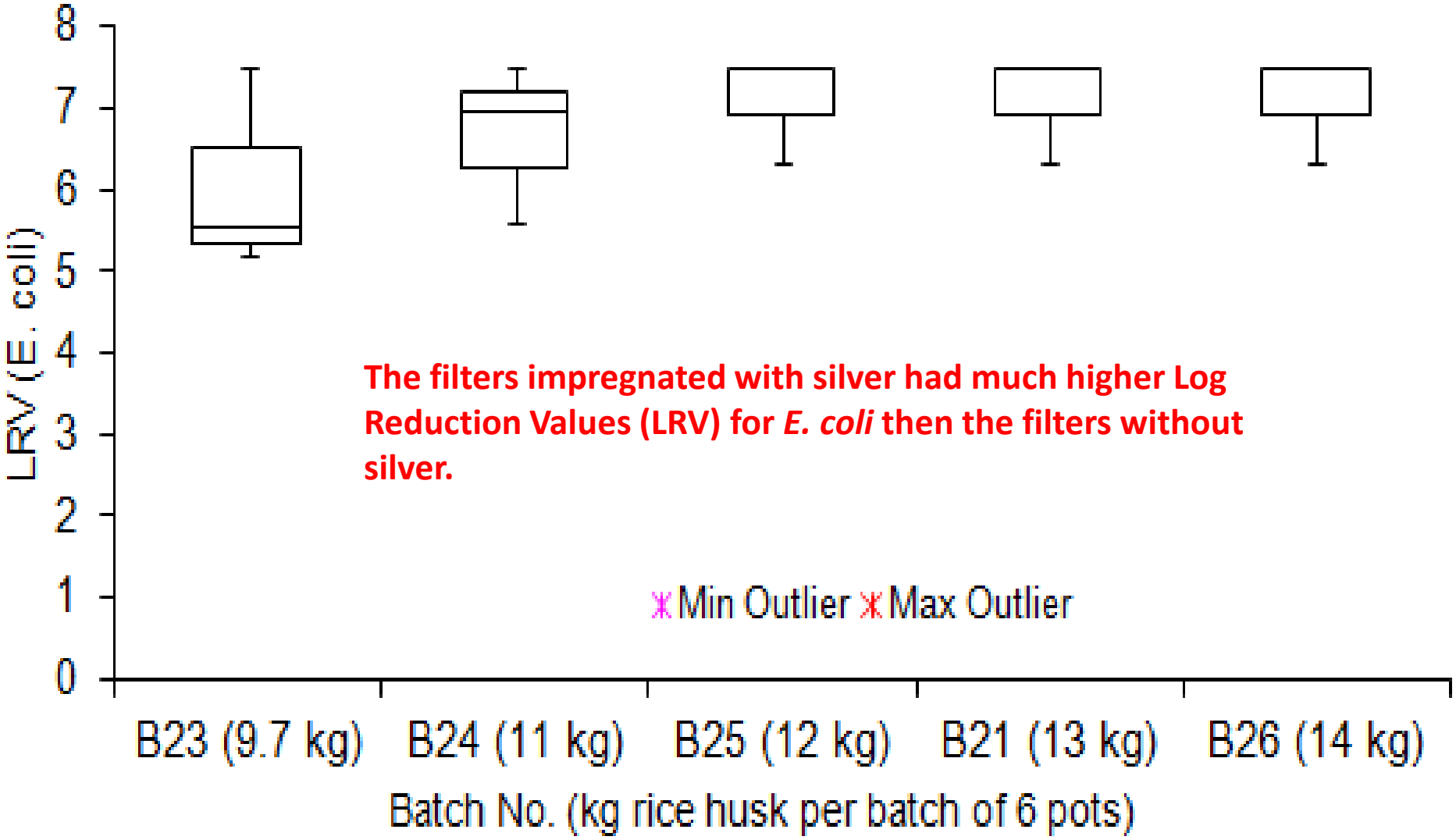


Results – Rice husk quantity variations
Second Batch Series (without Silver Nitrate)

Box-and-whisker plots

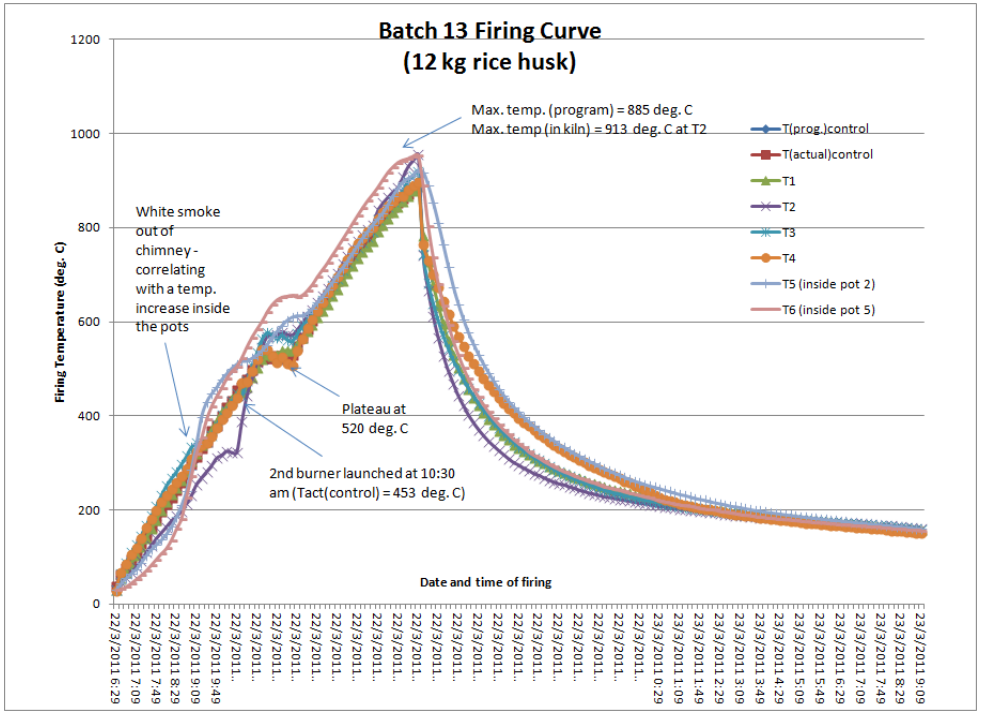


Results – Rice husk quantity variations
Second Batch Series WITH SILVER NITRATE



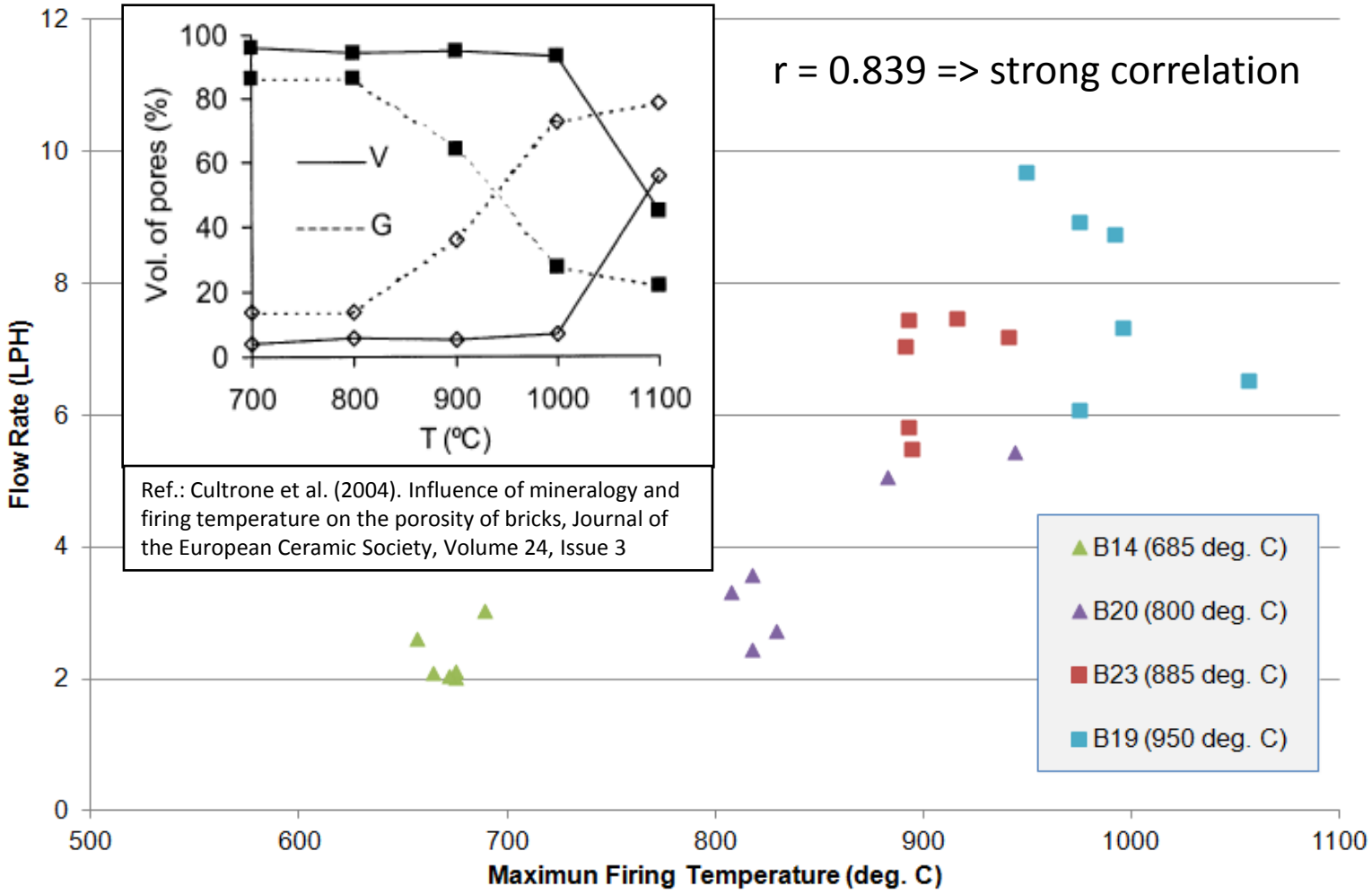
The filters impregnated with silver had much higher Log Reduction Values (LRV) for *E. coli* then the filters without silver.

RESULTS
Maximum Firing Temperature Variations



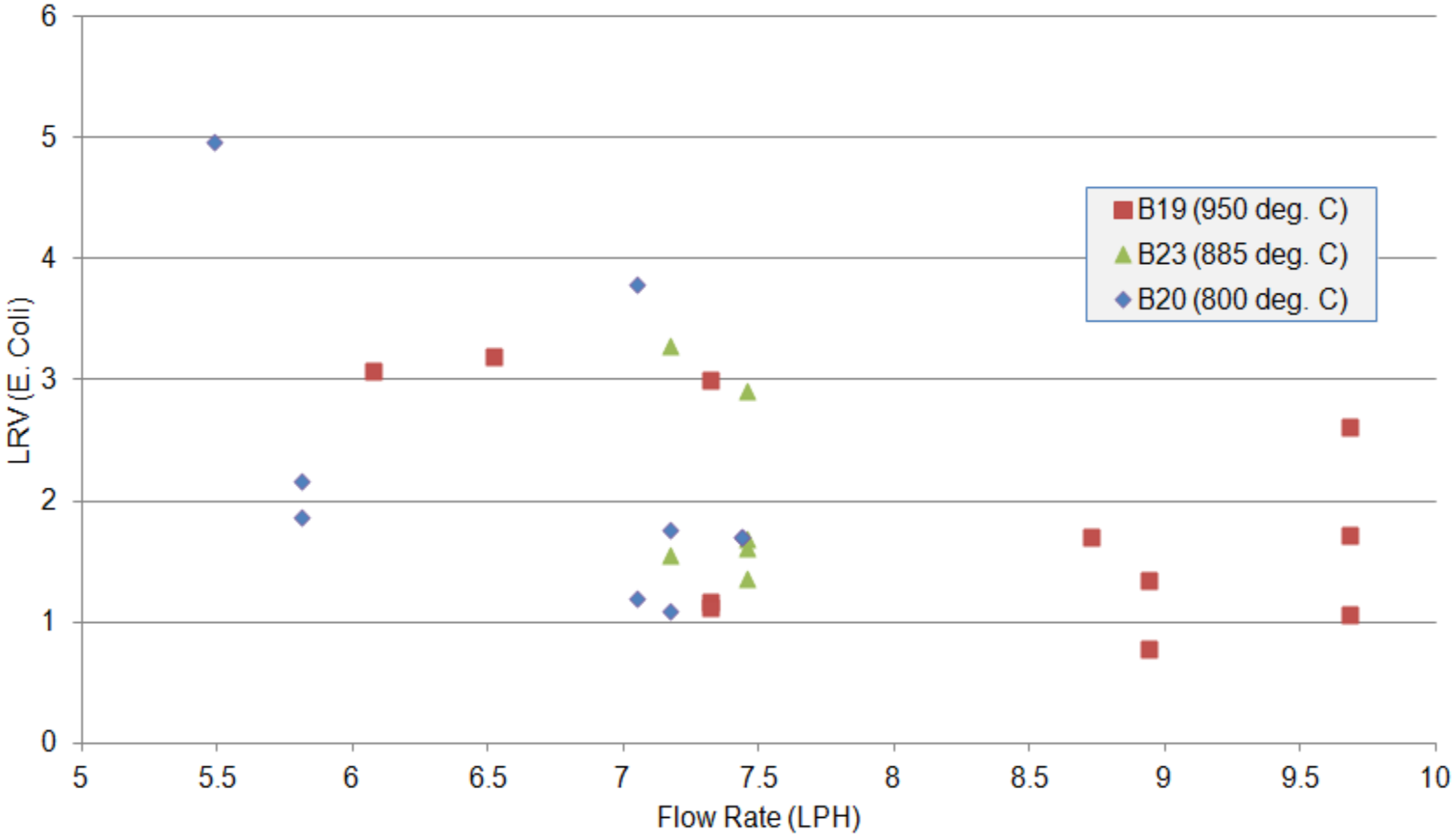
Results – Maximum Firing Temperature Variations

Flow Rates versus Maximum Firing Temperatures



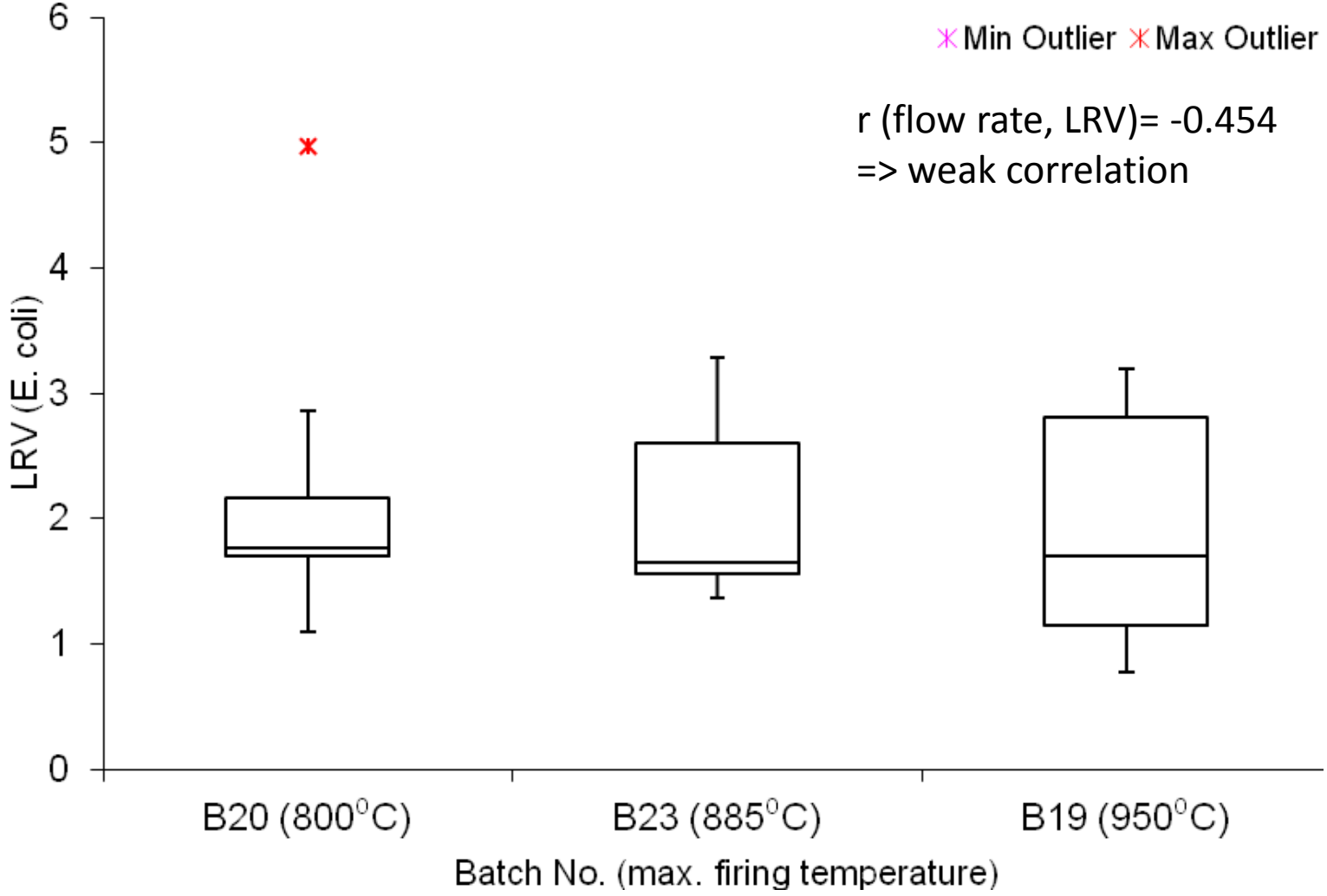
Results – Maximum Firing Temperature Variations

LRVs (E. coli) versus Flow Rates



Results – Maximum Firing Temperature Variations

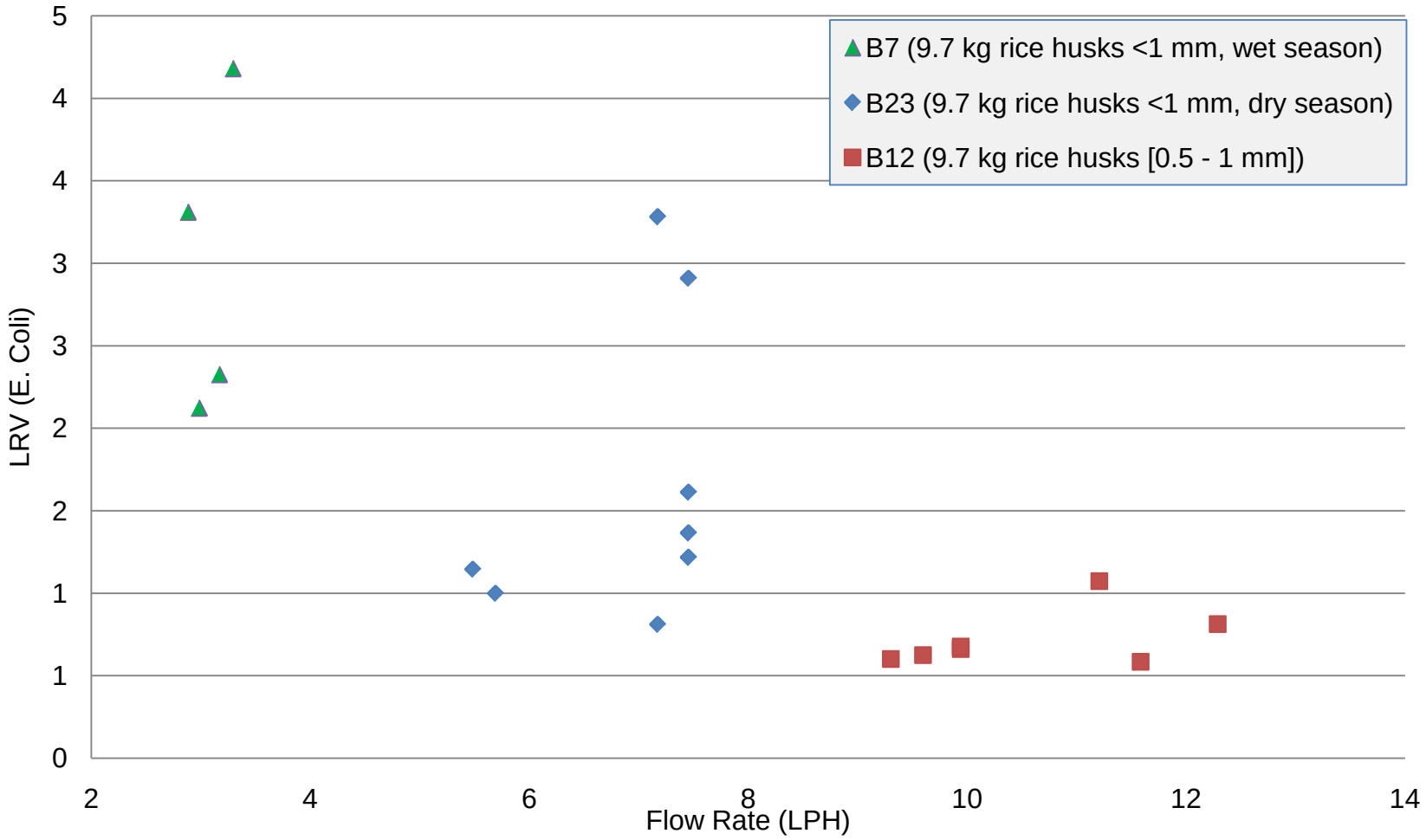
Box-and-Whisker Plots



RESULTS
Rice Husk Particle Size Variation

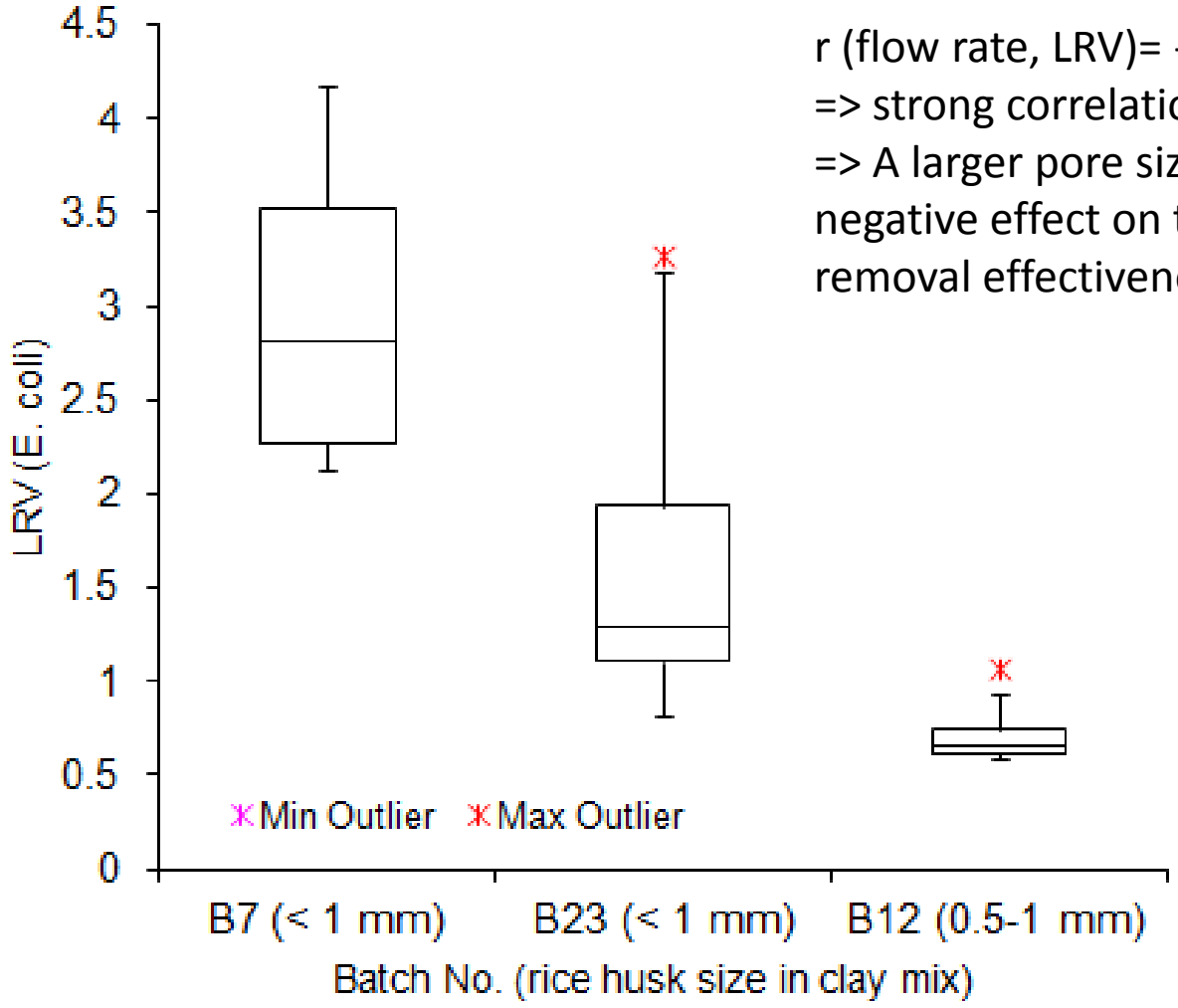
Results – Rice Husk Particle Size Variations

LRVs (E. coli) versus flow rates



Results – Rice Husk Particle Size Variations

Box-and-Whisker Plots

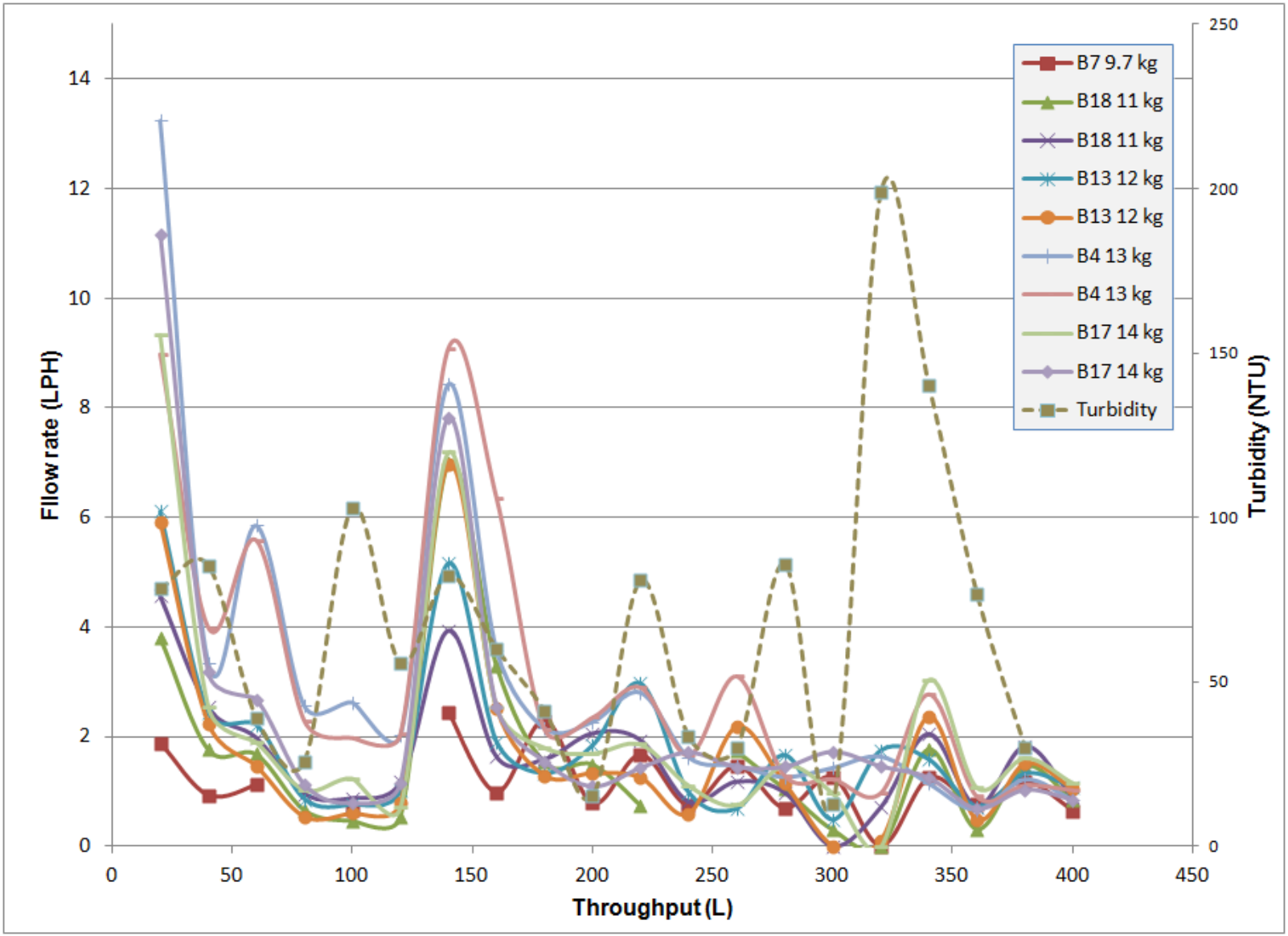


r (flow rate, LRV)= -0.693
=> strong correlation
=> A larger pore size has a negative effect on the bacteria removal effectiveness

RESULTS
Two-Month Clogging Test

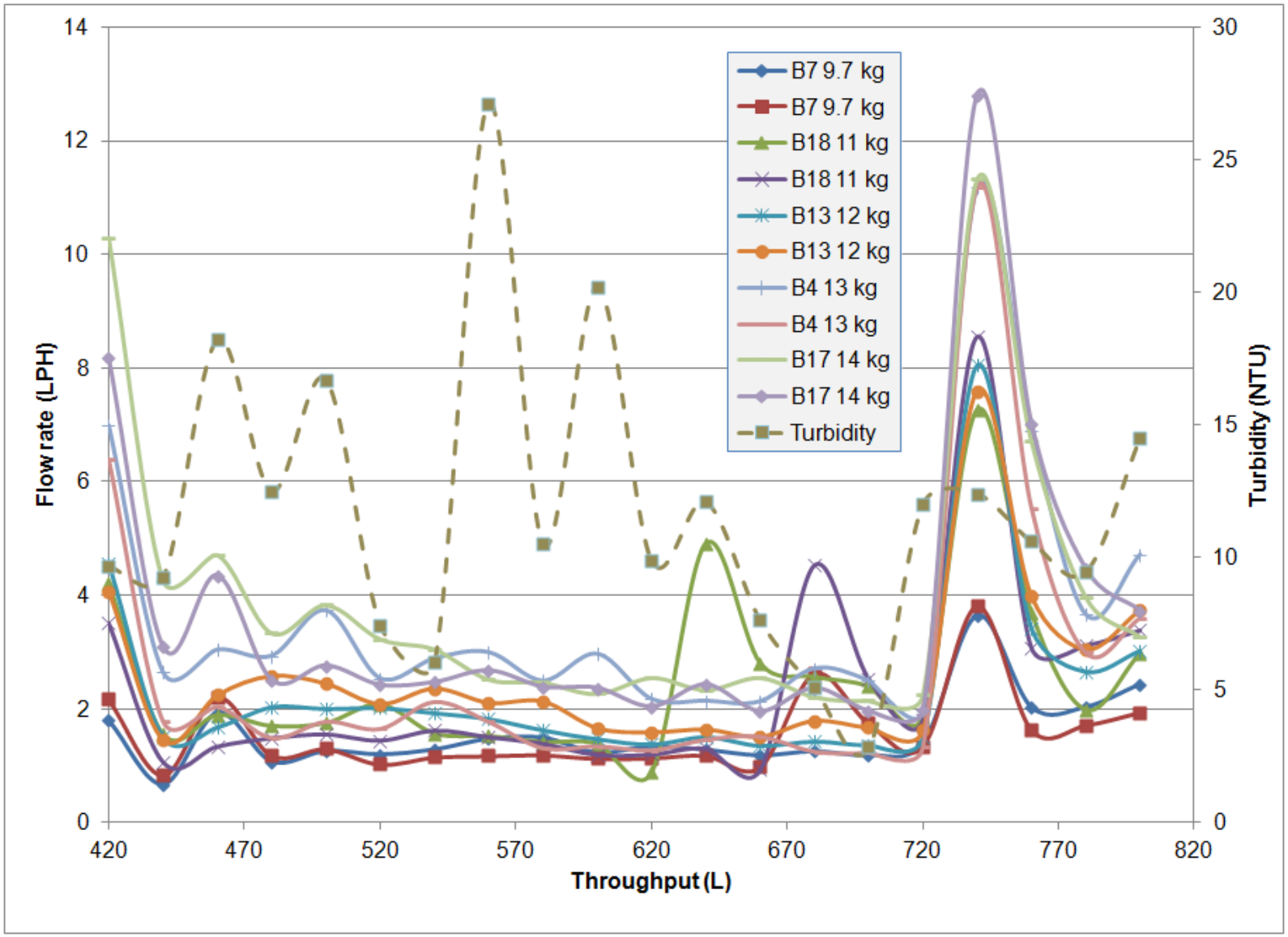
Clogging Test

using turbid pond water (12.9<NTU<199)



Clogging Test

using less turbid well water (2.7<NTU<27.1)



RESULTS
Strength Test

Strength

	Batch code	Average Modulus of Rupture (MPa)	*Coefficient of Variation*
Rice husk quantity variation	B23/B22	**2.40**	*21%*
	B24	**1.78**	*17%*
	B25/B9	**1.59**	*8%*
	B21/B8	**1.30**	*9%*
	B26	**1.27**	*29%*
Maximum firing temperature variation	B14	**1.08**	*18%*
	B20	**1.86**	*10%*
	B19	**2.91**	*20%*
Rice husk size variation	B12	**1.34**	*39%*
Control sample	RDIC	**4.55**	*21%*

$$\sigma = \frac{3F}{4\pi e^2}\left\{(1-\nu)\left[1+\ln\left(\frac{a}{\Theta}\right)^2+\left(\frac{a}{\Theta}\right)^2\right]-(1+\nu)\ln\left(\frac{b}{\Theta}\right)^2-\left(\frac{(1-\nu)}{2}\right)\left(\frac{b}{\Theta}\right)^2\right\}$$

Possible reasons for RDIC pots being stronger:

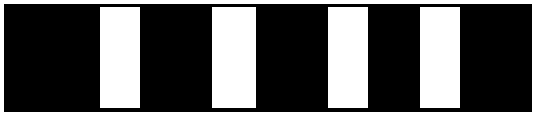
-pots inside the RDIC wood-fired kilns reach higher temperature

-the clay mixture is passed through the pug mill (no air pockets)

CONCLUSIONS
&
RECOMMENDATIONS

Conclusions

a) Standard pot with standard pores and standard porosity



b) Pot with a higher porosity but the same pore size. The flow rate is doubled compared to a)

c) pot with the same porosity but an increased pore size. The flow rate is higher than a)

The flow rate can be increased by:

1. **increasing the porosity** of the filter, by increasing the quantity of burn-out material in the clay mix; and
2. **increasing the pore size**, either by
   - changing the particle size distribution of the burnout material, or by
   - changing the maximum firing temperature.

The bacteria removal effectiveness is only compromised when increasing the pore size

Special Thanks

- **Everybody at RDI**, especially:
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Questions?