Assessment and Management of Chemical Risks in Academic Laboratories (3)

- Observing behavior of experimenter and chemical reagents in an actual chemical laboratory-

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Chemical Reagent Handling

In chemical laboratories, many chemical reagents are handled at various **places** for various **purposes** according to various **factors**.

fume hood	reactant	type of work (routine or new)
lab bench	solvent	number of experimenters
reagent storage cabinet	standard	time
waste container …	coolant …	scale (amount) …

To reduce the risk of chemical substances in laboratories, knowing <u>HOW</u> experimenters use chemicals is important.

Information currently available on Japanese universities

- Registration system of chemicals
- Laboratory waste management system

total quantity

- Working environment measurement
- Inspection by industrial physician

"steady-state" in routine operation

Characteristics of laboratory research

✓ use of large number of various chemical substances

approx. 350,000 chemical bottles in UTokyo (as of 2011) [1]

✓ transdisciplinarity and diversification of research areas

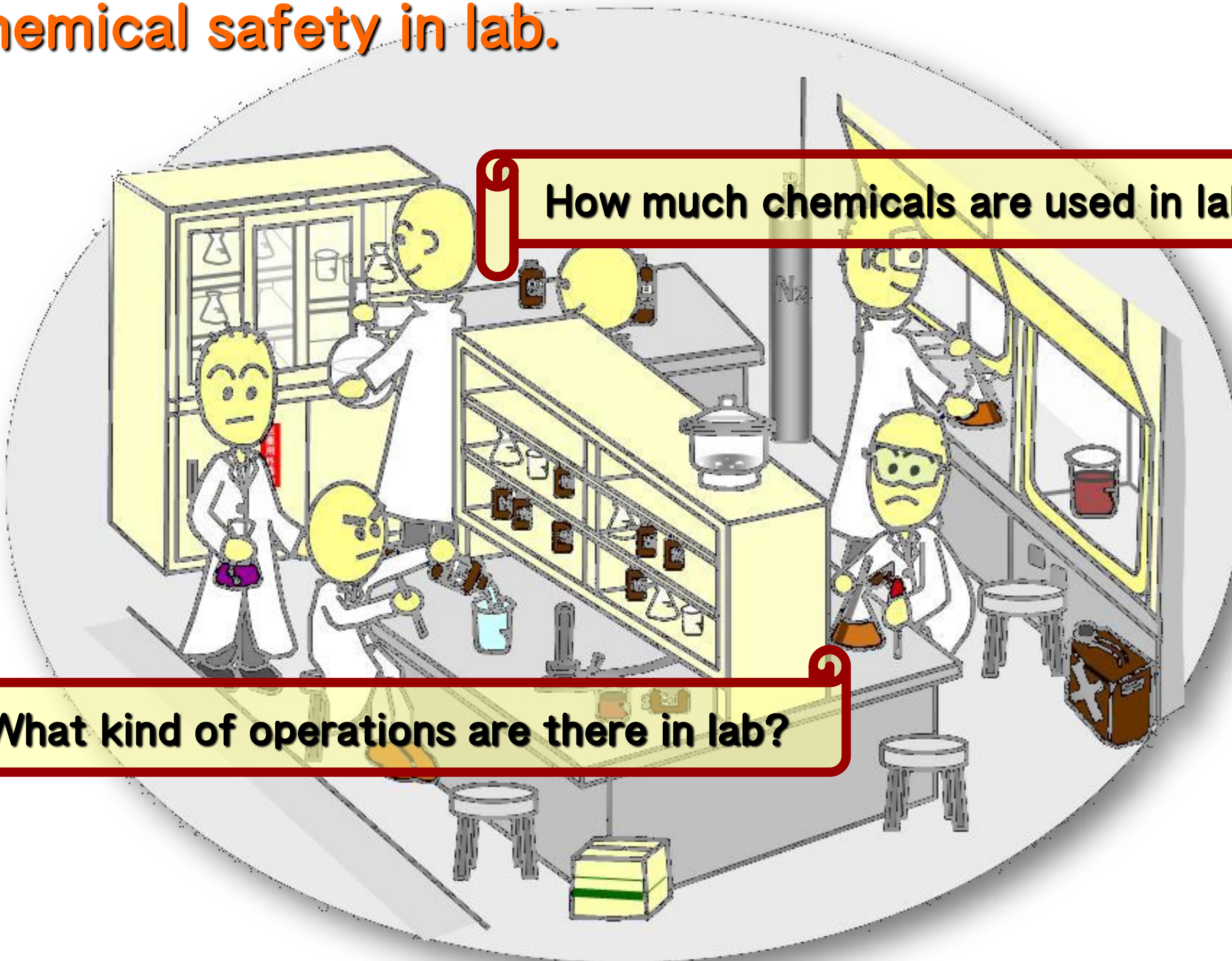
chemistry, physics, biology, physics, mechanics, pharmaceuticals ...

How should chemical risks be assessed in research labs?

[1] HAYASHI, R.; TONOKURA, K., *Asia Pacific Symposium on Safety 2011*, Korea, 2011.

Chemical safety in lab.

How much chemicals are used in lab?



What kind of operations are there in lab?

Chemical safety in lab.

- ✓ ***who*** uses chemicals
- ✓ ***what*** kind of chemical reagents are often used
- ✓ ***where*** chemicals are used
- ✓ ***when*** chemicals are used
- ✓ ***why*** chemicals needs to be used
- ✓ ***how*** chemicals are used

This information should be combined to analyze and reduce chemical risks in laboratories.

Case Study Approach

The characteristics in the usage of chemical substances in the chemical lab are analyzed by collecting the following data:

- movement of reagent bottles during experiments by Radio Frequency Identification (RFID) System
- experimenter actions captured by web cameras
- purpose and procedure of experiment

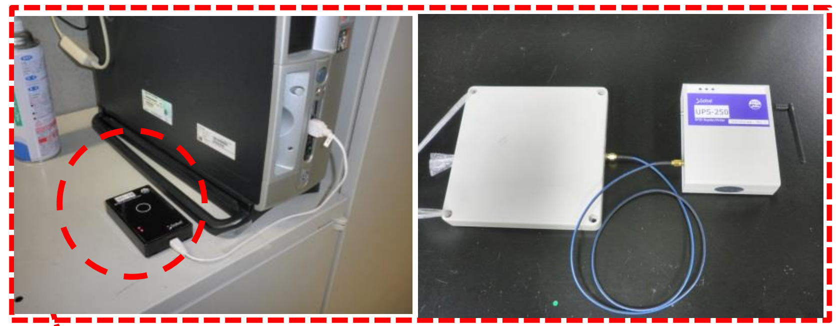
handling behavior of chemicals ⇔ place & layout
purpose of experiment
procedure

Y. Nezu, R. Hayashi, Y. Oshima, *Journal of Environment and Safety*, **5(1)**, 9-17 (2014).
Y. Nezu, R. Hayashi, Y. Oshima, *Journal of Environment and Safety*, **5(2)**, 99-105 (2014).

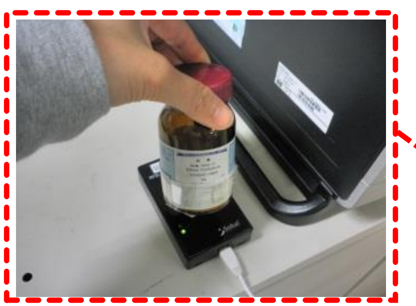
Radio Frequency Identification (RFID) System & Motion Monitoring by Web Cameras

All the chemical bottles in this lab (213 bottles) are "tagged"

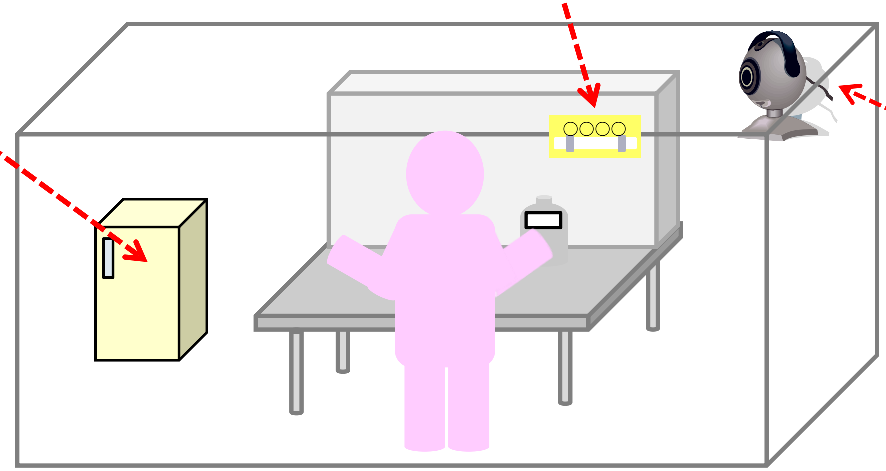
Device that reads "tag" from a distance using radio waves to identify objects



- recorded when chemicals are used at a designated location

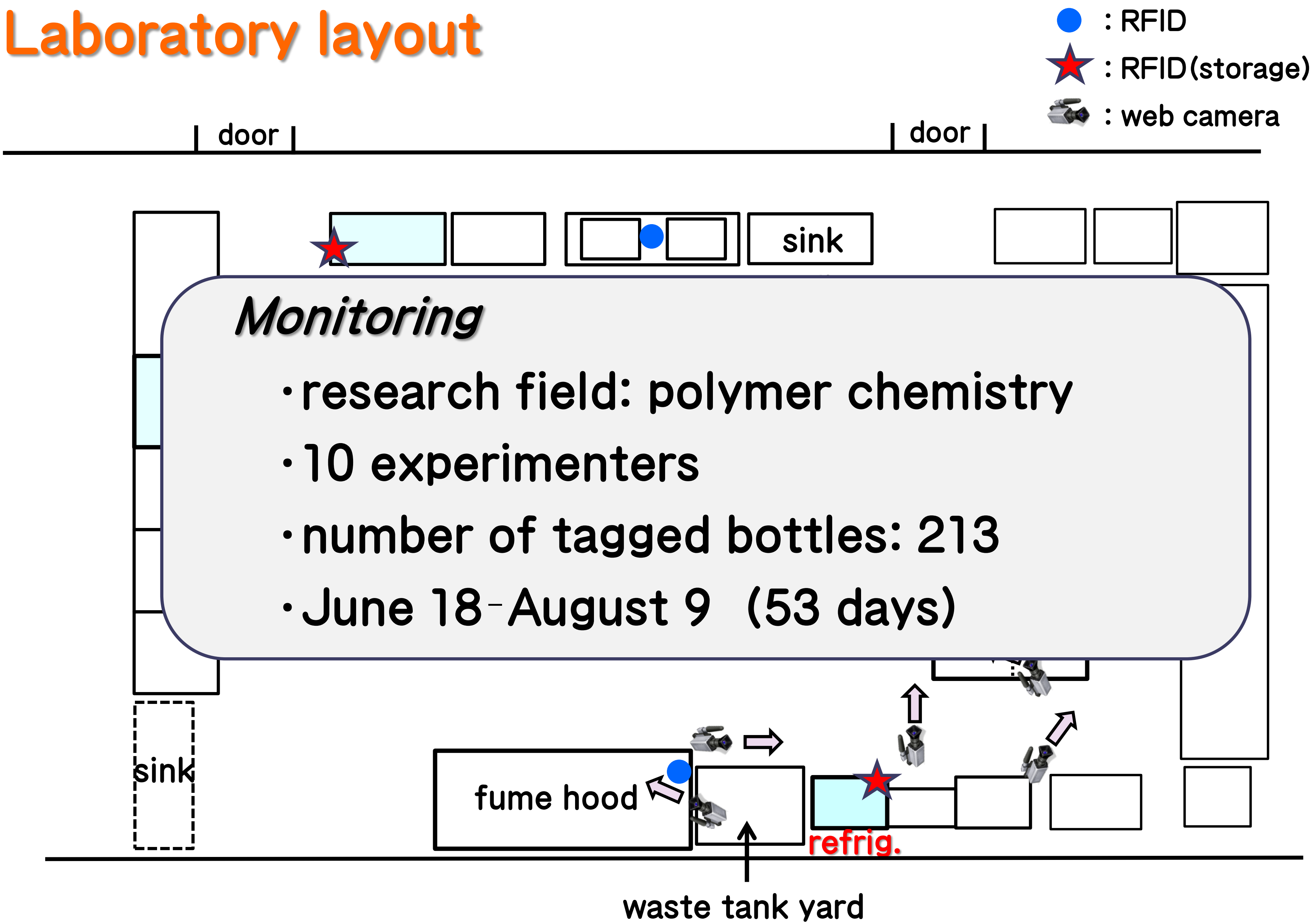


- checkout log of chemicals from storage



- motion of experimenters monitored by web camera

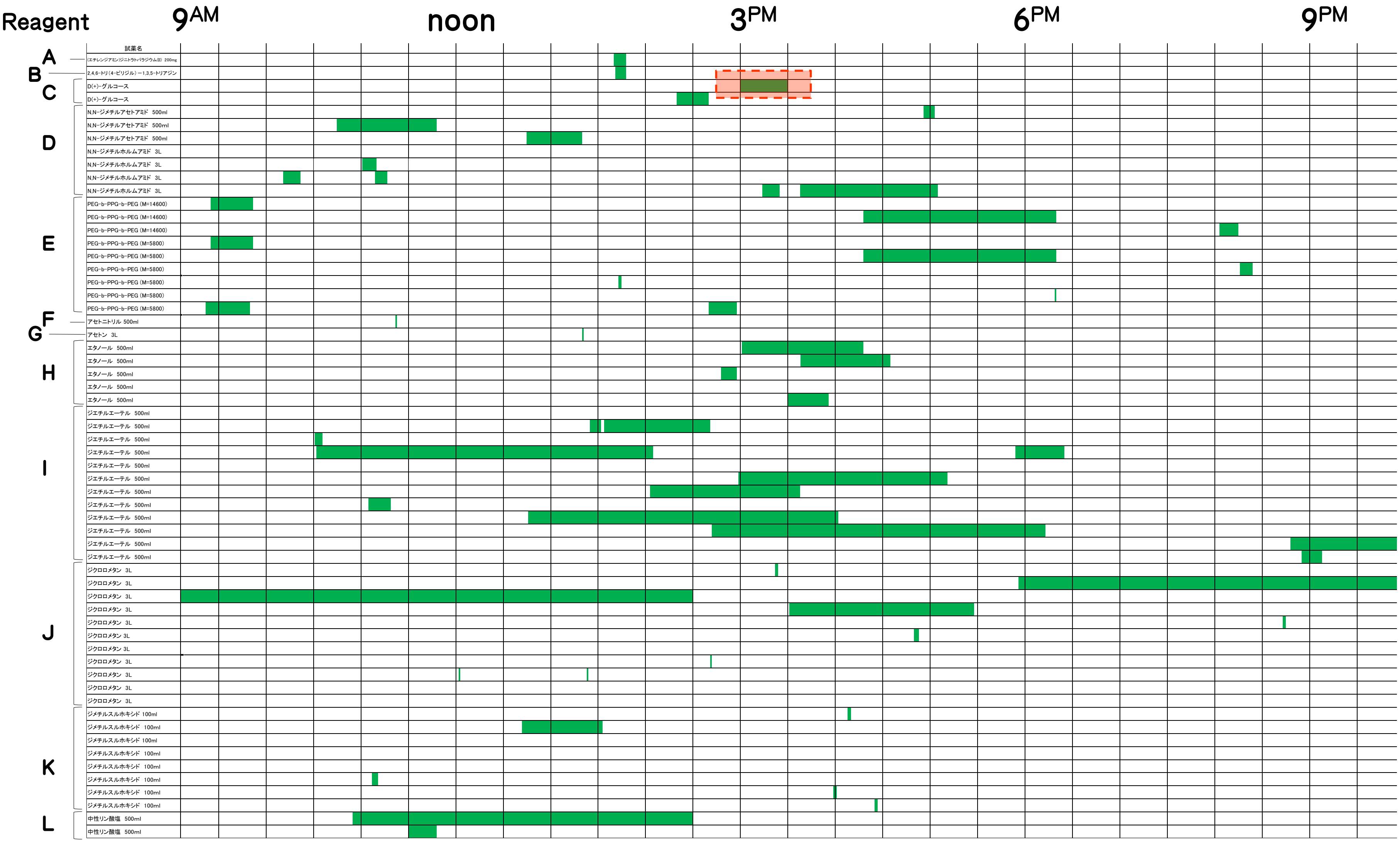
Laboratory layout



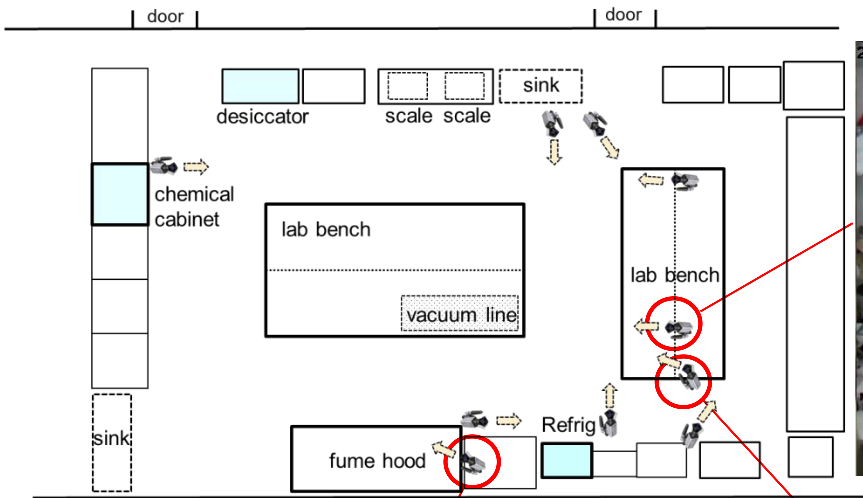
Monitoring

- research field: polymer chemistry
- 10 experimenters
- number of tagged bottles: 213
- June 18－August 9 (53 days)

Checkout log of reagents (example)



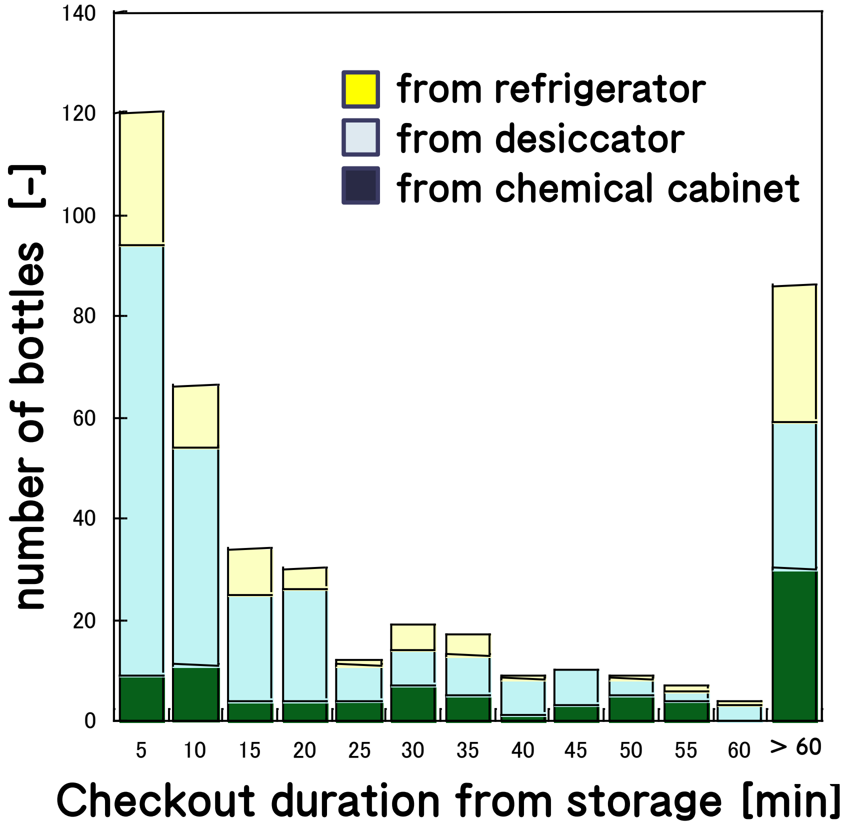
Experimenter actions (example)



Lab benches

Fume hood

Analysis on checkout log data of reagents



Checkout duration	refrigerator	desiccator	cabinet
less than 10 min	23.0 %	50.6 %	40.9 %
10 - 30 min	21.8 %	23.7 %	20.4 %
more than 30 min	55.2 %	25.7 %	39.8 %
Ave. checkout time [min]	73.3	26.1	48.9

43% of bottles returned to original storage within 5 mins.

- reagents from *refrigerator* — must be warmed up before use
- reagents from *desiccator* — disfavor humidity

Where chemicals are frequently used

Places where chemicals are frequently used

(July 1-July 5)

Place	Frequency
Lab bench	39
Fume hood	15
Scale	19
Total	73

Tracking of chemical bottles in lab

Place	Frequency	Place of usage	
Lab bench(L)	39	L	67%
Fume hood(F)	5	F	
Scale(S)	4	S	
L→F	4	F	33%
L→F→L	5	F	
F→L	1	F	
L→S	7	S	
L→S→L	4	S	
L→S→L→S	2	S	
S→L	2	S	

Lab bench functions as a critical "hub"

How long are chemicals used in the lab

	Start	Stop	Time	Operation	Reagent	Place
Day 1	10:45:00	10:51:00	0:06:00	measuring	PEG	scale
	10:52:54	10:55:10	0:02:16	measuring	4-dimethyl aminopyridine	scale
	10:55:30	10:55:35	0:00:05	loading	PEG, 4-dimethyl aminopyridine	scale
	13:33:46	13:34:21	0:00:35	measuring	N,N-dimethyl acetoamide	fume hood
	13:34:22	13:34:50	0:00:28	loading	N,N-dimethyl acetoamide	fume hood
	13:39:53	13:40:06	0:00:13	measuring	triethylamine	fume hood
	13:40:21	13:40:42	0:00:21	loading	triethylamine	fume hood
	14:37:24	14:38:45	0:01:21	measuring	2-bromoisobutyryl bromide	fume hood
	14:37:24	14:38:40	0:01:16	loading	2-bromoisobutyryl bromide	fume hood
Day 2	10:46:45	10:47:00	0:00:15	dissolution	N,N-dimethyl acetamide	lab bench
	10:47:03	10:47:45	0:00:42	dissolution	diethyl ether	lab bench
	11:16:13	11:16:29	0:00:16	measuring	methanol	fume hood
	11:16:13	11:16:28	0:00:15	measuring	methanol	fume hood
	11:17:15	11:17:41	0:00:26	loading	diethyl ether	fume hood
	11:17:15	11:17:35	0:00:20	loading	diethyl ether	fume hood
	11:25:10	11:28:02	0:02:52	measuring	reactant (mixture)	fume hood
	11:28:05	11:31:33	0:03:28	still standing	reactant (mixture)	fume hood
	11:31:35	11:32:25	0:00:50	loading	reactant (mixture)	fume hood
	11:32:20	11:32:25	0:00:05	loading	reactant (mixture)	fume hood
	11:37:08	11:37:25	0:00:17	washing	diethyl ether	fume hood
	11:37:08	11:39:41	0:02:33	washing	diethyl ether	fume hood
	11:38:34	11:38:37	0:00:03	washing	diethyl ether	fume hood
	12:32:10	12:35:22	0:03:12	loading	reactant (mixture)	fume hood
	12:36:07	12:36:24	0:00:17	washing	diethyl ether	fume hood

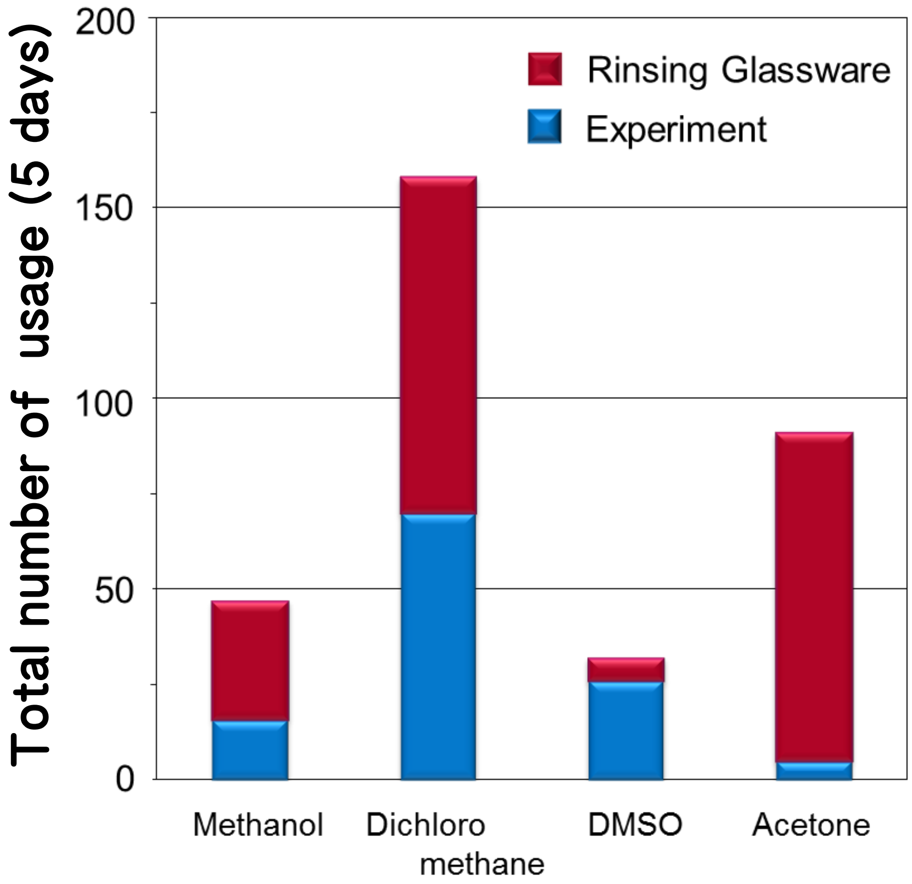
Length of time for chemicals to escape into air

Operation	length of time: open-air (a)	length of time: total (b)	ratio (a)/(b)
Extraction	17.5 min	60.8 min	28.7 %
Precipitation	4.1 min	23.5 min	17.4 %
Filtration	5.6 min	25.0 min	22.4 %

cf. total time length of entire experiment: 694 min

Chemicals escaping into the air for a certain length of time is unavoidable, though it may be negligibly short compared with the duration of the entire experiment.

Washing bottles



- **Purpose**

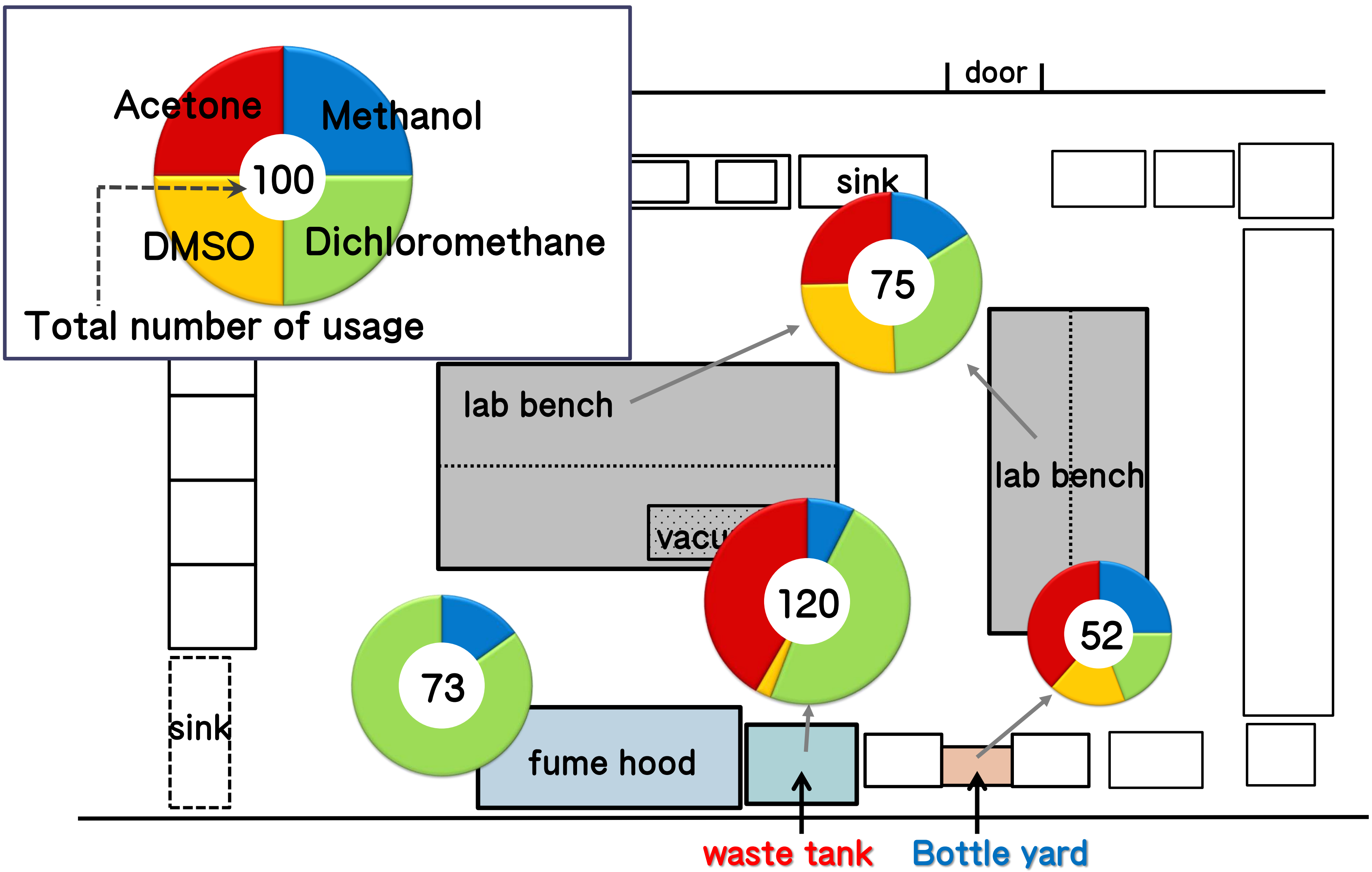
  64.3 % for rinsing glassware before and after use

- **Frequency**

  65.6 times/day (average)

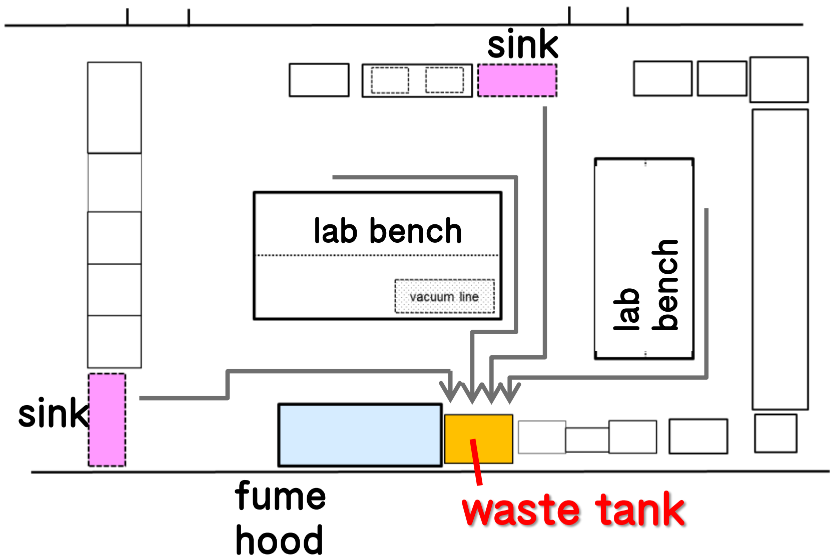
Y. Nezu, R. Hayashi, Y. Oshima, *Journal of Environment and Safety*, **6(2)**, 99-102 (2015).

How are washing bottles used in lab



Rinsing with “washing bottle”

- “non-essential” operation to experiment purpose
- as frequently as glassware used
- indefinite time until completion of rinsing
- indefinite place (bottle is movable)
- volatile solvents exposed to the air during operation until dumped into waste tank



⇩

a risky procedure that may influence on the chemical exposure

Experimental protocol (from Experimenter A's notebook)

three necked flask (50 mL)

- PEG 2 g
- DMAP 2.8 mg
- magnetic stirring bar
- vacuum drying (2 hrs.)
- replace with Ar
- DMAc (dehyd.) 8mL
- TEA 0.8 mL
- dissolved at 40 ^{o}C
- 2-BIB 0.22 mL
- stirring at 30 ^{o}C

separatory funnel (300 mL)

erlenmeyer flask (50 mL)

- ice bath
- ether 30 mL
- MeOH 0.2 mL

taking fraction (2 mL)

precipitation tube (50 mL)

- centrifugation
  3100 rpm, 15 min

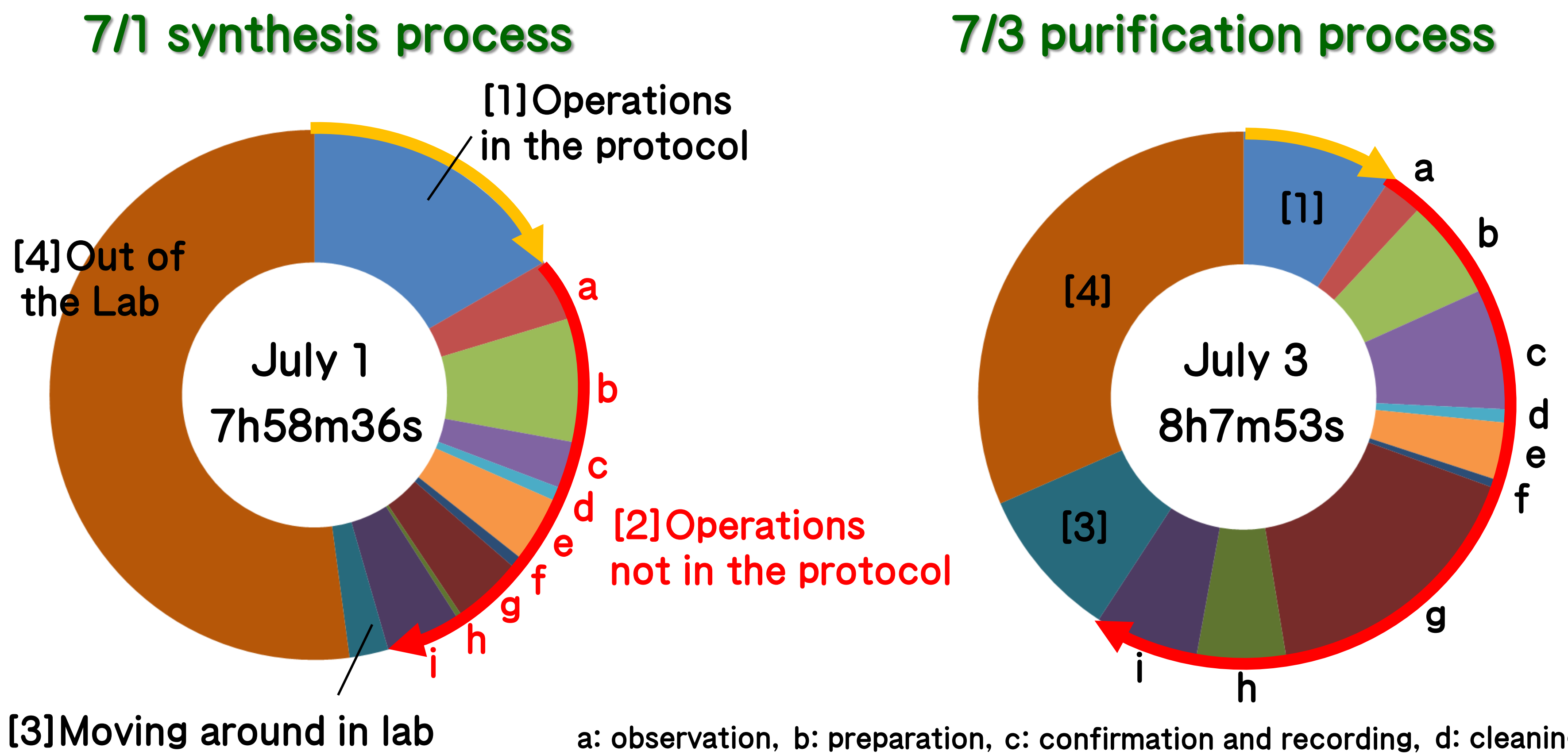
⋮

Classification of experimenter's behavior in lab

- in Lab
  - [1]operation in the protocol
  - [2]operation not in the protocol
  - [3]moving around in Lab
- [4]not staying in the laboratory

a: observation
b: preparation
c: confirmation and recording
d: cleaning
e: exit operations
f: protection
g: changes and adjustments
h: others
i: non-experimental

Distribution of time-duration classified by type of operation



a: observation, b: preparation, c: confirmation and recording, d: cleaning, e: exit operations, f: protection, g: changes and adjustments, h: others, i: non-experimental

Risks during operation "not in the protocol" are crucial!

Summary

Chemical reagent behavior and experimenter behavior in an actual laboratory analyzed through a case study approach.

Chemical Reagent Behavior
- outing from storage
- trajectory characteristics

Experimenter Behavior
- time duration for operation
- chemical usage

Discussed: how key unit operations affect chemical exposure

Confirmed as crucial:
- ➢ risk in operations not in protocol
- ➢ handling chemicals in “shared circumstances

Laboratology concept is critical for …

scientific and quantitative discussion based on data of visible, measurable phenomena collected in actual laboratories

… assessing chemical risks in experimental laboratories.

Acknowledgement

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