





In all areas the technical binding time was higher than the Takt-Time, so machine capacity was needed to be raised up. The employee binding time in all steps was lower than the Takt-Time. The formula for the calculation of the needed staff was:

$$\frac{\text{Process EBT} * \text{Number of samples} * (1 + \text{fluctuation})}{\text{working time per employee}} = \text{needed staff}$$

The result had to be rounded up in every case, as full employees are needed for the process steps. A total number of 11 lab technicians were needed, the results are shown in Table 5. Thereof four were needed in the Water-Lab-Team, five in the Soil-Lab-Team and two in the Emission-Lab-Team.

Table 5: Necessary staff

Matrix	Process EBT	No of samples	fluctuation	working time	theor. staff	round up
Water	75 min	20	20%	480 min	3.75 FTE	4 FTE
Soil	55 min	30	20%	480 min	4.12 FTE	5 FTE
Emission	75 min	10	20%	480 min	1,9 FTE	2 FTE

The second step was to implement standardized work in consideration of the Just in Time and Jidoka pillar. Standardized work doesn't mean the classical "standard operation procedure" (SOP), as in addition to the classical method description also a detailed handling step order need to be implemented. It is necessary to also document where the operation Line start, how exactly the lab technicians must handle the samples, or in which step the sample must handed over to the next employee.

As the standardized work implementation was planned, it was also necessary to analyze how it could be possible to implement continuous sample flow. One-Piece-Flow is the supreme discipline but if the regulation required a blanc or quality sample for every clean up, if the work flow is interrupted by a delay due to e.g. waiting time for a proper phase separation or if a technical step can only procedure a bigger amount of samples at ones it made no sense to implement One-Piece-Flow.

All attempts were made to get the lowest possible batch size in every analyzing line. Therefore, it was important to understand what step decide the batch size. In this case the mechanical extraction system for water and soil, as it was only possible to start all three samples at ones. For Emission it was the phase separation of the liquid/liquid extraction. The decision was, to use batches of 3 samples for Water and Soil and batches of 5 samples for Emission. But the batch operation was only used into the steps where it was necessary all other steps like registration, homogenization or measurement One-Piece-Flow was implemented, that gave the possibility for continuous improvement. Table 6 to Table 8 document the workload in all analytical lines.<sup>5-7</sup>

Table 6: Workload Table for Water (process-time up to 25h; ① = 2<sup>nd</sup> day)

Prozess   Time	8am	9am	10am	11am	12am	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm
Registration	BW ①-②	③-⑤	⑥-⑧	⑨-⑪		⑫-⑭	⑮-⑰	⑱-⑳					
Dividing	BW ①-②	③-⑤	⑥-⑧		⑨-⑪	⑫-⑭	⑮-⑰	⑱-⑳					
Filtration	BW ①-②	③-⑤		⑥-⑧	⑨-⑪	⑫-⑭	⑮-⑰	⑱-⑳					
Liquid/Liquid		BW ①-②	③-⑤	⑥-⑧	⑨-⑪		⑫-⑭	⑮-⑰	⑱-⑳				
Solid/Liquid				BW ①-②	③-⑤	⑥-⑧		⑨-⑪	⑫-⑭	⑮-⑰	⑱-⑳		
Evaporate lq/lq		BW ①-②	③-⑤	⑥-⑧		⑨-⑪	⑫-⑭	⑮-⑰	⑱-⑳				
Clean up					BW ①-②	③-⑤	⑥-⑧		⑨-⑪	⑫-⑭	⑮-⑰	⑱-⑳	
evaporate					BW ①-②		③-⑤	⑥-⑧	⑨-⑪	⑫-⑭	⑮-⑰	⑱-⑳	
Measurement	⑩-⑳ Tunni ng	Cal check	Tuloen e			BW	①	②	③④	⑤	⑥	⑦⑧	⑨
Data evaluation	⑩-⑫	⑬-⑮	⑯-⑰	⑱-⑳			BW, ①	②	③	④-⑤	⑥	⑦	⑧-⑨
Report	⑩-⑫	⑬-⑮	⑯-⑰	⑱-⑳			BW, ①	②	③	④-⑤	⑥	⑦	⑧-⑨

Table 7: Workload Table for Soil (process-time up to 40h; ① = 2<sup>nd</sup> day)

Prozess   Time	8am	9am	10am	11am	12am	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm
Registration	BW,QS ①-⑤	⑥-⑨	⑩-⑭	⑮-⑲	⑳-㉓	㉔-㉗	㉘-30						
Homogenization	①-④	⑤-⑧	⑨-⑬	⑭-⑱	⑲-㉒	㉓-㉖	㉗-30						
Extraction				BW,QS ①-③	④-⑥	⑦-⑫	⑬-⑮	⑯-⑱	⑲-㉒	㉓-㉗	㉘-30		
Clean up					BW,QS	①-⑥	⑦-⑨	⑩-⑫	⑬-⑱	⑲-㉒	㉓-㉗		㉘-30
evaporate					BW,QS	①-③	④-⑨	⑩-⑫	⑬-⑮	⑯-㉒	㉓-㉖	㉗-㉙	㉚-30
Measurement	⑩-30 Tunning	Cal check	Tuloen e				BW,QS			①-③		④-⑥	⑦-⑨
Data evaluation	⑦-⑨	⑩-⑫	⑬-⑮	⑯-⑱	⑲-㉒	㉓-㉖	㉗-㉙	㉚-30		BW,QS	①-③		④-⑥
Report	⑦-⑨	⑩-⑫	⑬-⑮	⑯-⑱	⑲-㉒	㉓-㉖	㉗-㉙	㉚-30			①-③		④-⑥

Table 8: Workload Table for Emission (process-time up to 32h; ① = 2<sup>nd</sup> day)

Prozess   Time	8am	9am	10am	11am	12am	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm
Registration	①-⑤		⑥-⑩										
Filtration	①-⑤		⑥-⑩										
Liquid/Liquid		①-⑤		⑥-⑩									
Solid/Liquid	①-⑩												
Evaporate	①-⑤	⑥-⑩											
Clean up			①-⑤	⑥-⑩									
evaporate			①-⑤		⑥-⑩								
Measurement	Tunning	Cal check	Tuloen e	①	②-③	④	⑤	⑥-⑦	⑧	⑨	⑩		
Data evaluation							①-②	③-⑤	⑥-⑧	⑨-⑩			
Report													

## Conclusions

The classical contract laboratory with a high sample amount and matrix diversity sometimes needed several weeks to analyze all samples, depending on the fluctuation of sample amount and employees.

The here shown Lean implementation was able to give big labs (> 10,000 samples for PCDD/F and PCB per year) a higher cash flow and profitability. Without production planning and a fluctuating sample amount, also the cash flow decreases because the samples need a longer time until invoicing. With the everyday production planning the same number of samples will be reported and with the report also invoiced in a continual flow. The profitability increased because of the optimized amount of staff and instruments. The staff will be less stressed and stayed longer into the company. Shorter reaction times are possible, if the behavior of the customers change (matrix mix or number of samples).

Summarized Lean implementation means:

$$\text{Highest Quality} + \text{Shortest Delivery Time} = \text{Lowest Costs}$$

Lowest costs and a high profitability are the results not the goal of Lean and this results in continuous flow, continuous improvement and reduction of waste.

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