Environmental Aspects of Generating Vacuum

Summary

Many working steps in the laboratory necessitate the use of vacuum. For generating vacuum a water-jet vacuum pump on the one hand and vacuum pumps (oil and membrane pumps) on the other hand can be used. Vacuum should only be used if it is really necessary, because of the material and energy consumption and the entailed pollution. If vacuum must be employed in a work step water-jet vacuum pumps must not be used any more. It is more favourable using vacuum pumps if the technical possibilities on site allow it. Speed controlled pumps should be chosen from the big supply of vacuum pumps.

The Environmental Pollution of Generating Vacuum

The use of vacuum is an indispensable component of many work steps in the laboratory. Application areas are distillation and sublimation under reduced pressure as well as drying and filtration. In the field of laboratory work vacuum can be provided by water-jet vacuum pumps or oil and membrane pumps. As in the case of applying energy (see there) it could be shown that the generation of vacuum produces an adequate or higher pollution corresponding to the real conversion because of the required energy.

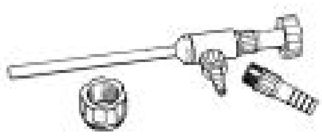

Fig. 1: Example of a water-jet pump

Fig. 2: Example of a vacuum pump

Which method of generating vacuum is most favourable from the pure ecological point of view cannot and should not be solved finally in this text. A valid conclusion about this question can only be made by analysing different systems and evaluating with help of an holistic assessment method. Although a detailed examination is indispensable for dependable statements the most favourable method of generating vacuum can be estimated under consideration of kind and dimension of the different environmental impacts. For this estimation several laboratory devices for generating vacuum were analysed with regard to their material and energy consumption and this consumption was thereupon evaluated.

The Application of Water-Jet Vacuum pumps

In water-jet vacuum pumps water on pressure was discharged through a driver connection. The downstream nozzle converts static energy to kinetic energy through which the velocity of the adrifting flow is increased. Behind the nozzle arises a zone with less pressure.

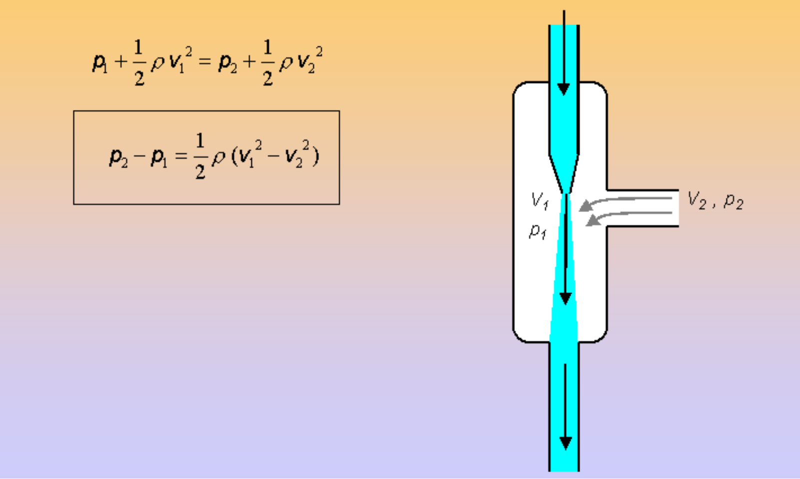

Fig. 3: Functional principal of water-jet vacuum pumps

Because of the vapour pressure of water the use of water-jet vacuum pumps is limited to jobs with less quality requirements for the vacuum (≥ 16 hPa). Another disadvantage of water-jet vacuum pumps is that volatile remaining substances (solvents) are getting into the sewage inevitably in the laboratory practice. The sucking performance of water-jet vacuum pumps is also lower compared to vacuum pumps. The positive site of using water-jet vacuum pumps is the comparable low purchase cost and the obviously lower ecological burden of producing the equipment.

For giving a statement about the pollution caused by employing water-jet pumps different devices were analysed. The average energy consumption of providing drinking water was determined in a survey.

Water Consumption in Generating Vacuum

For the assessment of water consumption of water-jet vacuum pumps in generating vacuum three water-jet pumps of different manufactures were compared. Following experimental structure (Fig. 4) was used for this:

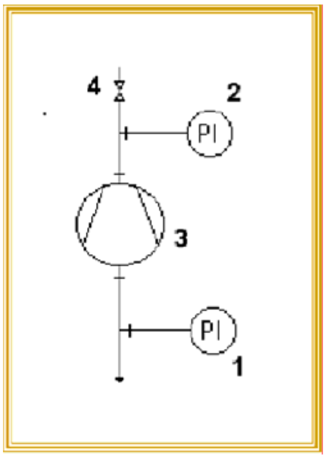

Fig. 4: Construction for the measurement of the water consumption of water-jet pumps
1. pressure gauge sucking side, 2. pressure gauge water side, 3. water-jet vacuum pump,
4. control valve

The analysed water-jet vacuum pumps reached their maximum depression after several minutes. The fuel-line pressure of 4.8 bar has been constant during the whole measurement. Table 1 shows the consumption of water determined for the different water-jet pumps.

	Water-jet vacuum pump			
	Synthetic material	Glass 1	Glass 2	
Vacuum Start	40	40	40	hPa
Vacuum after 20 min	26	36	34	hPa
Water consumpion	8,74	6,95	6,57	L/min

Table 1: Water consumption of water-jet pumps

As mentioned before it is true that no electric power is used up in the generation of vacuum by means of water-jet pumps but in the production and supply with drinking water.

Water-Jet Vacuum Pumps – Energy Consumption in Preliminary Chains

The energy used up for producing and providing drinking water for example by pumps is to be assigned directly to the generation of vacuum by means of water-jet pumps. Furthermore the material and energy flows for manufacturing the products that are needed in the work up of drinking water must be taken into account. The manufacture of chlorine or corrosion prevention substances for the preservation of the supply network belongs to this. Table 2 contains data about energy and material consumption of the drinking water provision from various water providers.

Water work	Produced amount of drinking water (m^3)	Electrical energy (kWh/m^3)	Chlorine (g/m^3)	NaOCl (g/m^3)	Corrosion prevention (g/m^3)
1	2655000	1,28	0,29	0,72	6,48
2	6852136	0,94	0,23	0,31	0,68
3	9813655	0,35	0,12	0,00	0,00
4	10970963	0,21	0,06	0,97	1,45
5	1236547	0,66	0,00	0,40	0,00

Table 2: Energy and material consumption of the drinking water provision

On average about 670 Wh (1 Wh = 3.6 kJ) energy per m^3 drinking water are needed following these information. With it results an energy consumption of about **5 Wh/min** as pollution additional to the water consumption on an average water consumption of a water-jet vacuum pump of approximately 7 L/min.

After the material and energy consumption of different water-jet vacuum pumps were determined the usage of vacuum pumps is to be analysed in the following paragraph.

The Usage of Vacuum Pumps

Vacuum pumps run by electricity can be used alternatively to the usage of water-jet vacuum pumps. Their disadvantage in general is the high price of provision compared with a water-jet vacuum pump. Further disadvantages for example are the arising of waste oil in oil pumps or the necessity of installating cryo traps for condensing and with it holding back waste substances. For comparing water-jet pumps and vacuum pumps different pumps were analysed with regard to their energy consumption.

Vacuubrand Model "MZ 2C/1,7"

The model Vacuubrand MZ 2C/1,7 (sucking performance 2.4 m^3/h; final pressure < 15 hPa) is a classical membrane pump.

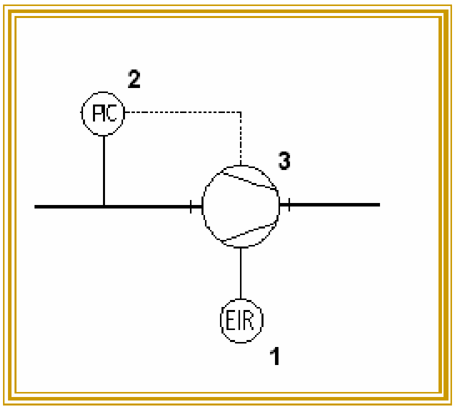

Fig. 5: Structure for measuring the energy consumption – membrane pump
1. energy measurement, 2. pressure setting/control, 3. membrane pump

Vacuubrand Modell MZ 2C/1,7			
	Experiment no.	1013 hPa	60 hPa
Consumption (Wh/min)	1	3,08	2,58
	2	3,10	2,52
	3	3,06	2,61
	4	3,07	2,53
	5	3,04	2,51
	6	3,07	2,63
	7	3,03	2,56
	8	3,04	2,60

Table 3: Energy consumption vacuum pump Vacuubrand MZ 2C/1,7

At full gaseous load the pump exhibits a consumption of approximately 3.1 Wh/min, without gaseous load it shows a consumption of about 2.6 Wh/min at a maximum pressure of 60 hPa (table 3). The energy consumption with and without gaseous load is to be regarded as approximately equal. That is why an average energy consumption of 2.8 Wh/min is assigned to the pump irrespectively of the gaseous load.

Oil Pump Leybold/Heraeus Model "trivac D2A"

The analysed rotary vane vacuum pump Leybold/Heraeus Model trivac D2A (sucking performance 2.0 m³/h) shows approximately equal energy consumption at all tested pressures. It is 5.4 Wh/min on average (table 4).

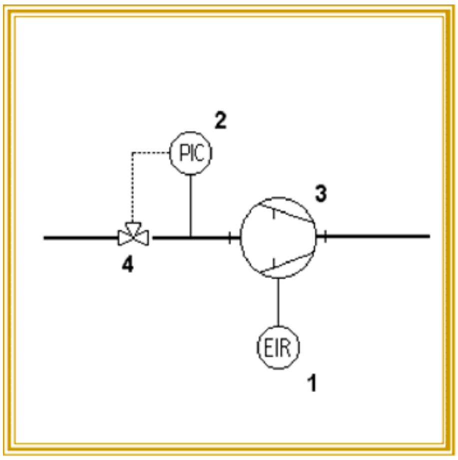

Fig. 6: Structure for measuring the energy consumption – rotary vane vacuum pump
1. energy measurement, 2. pressure setting/control, 3. rotary vane pump, 4. three-way valve

Oil pump Leybold/Heraeus Modell trivac D2A					
	Experiment no.	1010 hPa	600 hPa	200 hPa	1 hPa
Consumption (Wh/min)	1	5,28	5,36	5,52	5,52
	2	5,12	5,36	5,50	5,55
	3	5,28	5,35	5,52	5,60
	4	5,24	5,34	5,51	5,69
	5	5,23	5,35	5,53	5,53
	6	5,26	5,54	5,48	5,73
	7	5,24	5,16	5,51	5,59
	8	5,25	5,34	5,52	5,60

Table 4: Energy consumption of vacuum pump Leybold/Heraeus Model trivac D2A

Vacuubrand Pump stand Model "CVC 2000"

This vacuum pump (sucking performance 1.6 m³/h; final pressure < 2 hPa) is a speed controlled oil pump, that means vacuum is not adjusted by a ventilation as usual but is regulated addicting to the revolutions per minute.

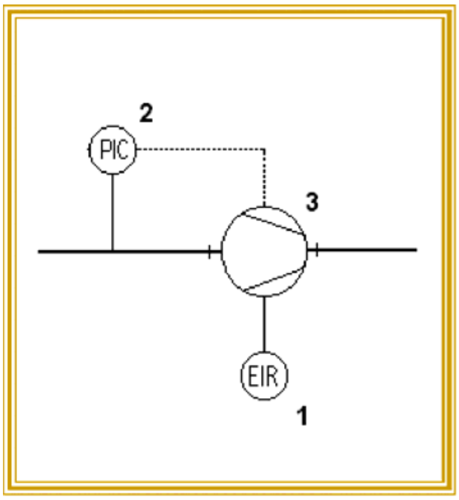

Fig. 7: Structure for measuring the energy consumption – pump stand
1. energy measurement, 2. pressure setting/control, 3. membrane pump

The measurements resulted in an average consumption of 0.94 Wh/min at fully gaseous load. The measurements at lower pressures are less representative because the pump stops on its own at reaching the target pressure. Therefore it will be assumed that the energy consumption in operation lies above the values given in table 5, but below the consumption at full gaseous load.

Speed controlled vacuum pump Vakuubrand "CVC 2000"					
Consumption (Wh/min)	Experiment no.	1010 hPa	600 hPa	200 hPa	3 hPa
	1	0,65	0,15	0,23	0,18
	2	0,96	0,12	0,11	0,16
	3	0,95	0,12	0,12	0,19
	4	0,94	0,12	0,12	0,18
	5	0,93	0,13	0,11	0,19
	6	0,93	0,12	0,12	0,17
	7	0,94	0,12	0,11	0,19
	8	0,92	0,13	0,12	0,18

Table 5: Energy consumption vacuum pump Vacuubrand CVC 2000

Results

Similar to the operation of heating (see there) the usage of vacuum has also an immediate effect on the material and energy consumption of a synthesis and therefore affects its pollution potential. Because of the fact that generating vacuum often takes up the largest share in the total energy consumption of a reaction vacuum should only be employed if other methods of separating do not result in the expected effect.

A high consumption of water and a analogue energy consumption compared with vacuum pumps result in a high total pollution of water-jet pumps. Therefore vacuum pumps should be used instead of water-jet pumps for generating vacuum from the ecological point of view.

Among the great number of available vacuum pumps those should be used from the ecological point of view which change their sucking performance by means of speed control.