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of the

Grundfos Ground-Water Sampling Pump

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Compliments of Grundfos Pumps Corporation

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Abstract

One major criteria of the "ideal" ground-water sampling device is that it be able to purge a monitoring well of stagnant water at a relatively high rate of flow (e.g., more than 10 liters per minute) and be able to sample ground water at a low flow rate (e.g., 0.1 - 1 liter per minute) so as not to impact the integrity of the sample. Sampling devices for two-inch diameter wells generally have been able to deliver water at low flow rates, but have been relatively ineffective during the purging phase because their maximum flow rates are generally less than four to six liters per minutes.

Grundfos Pump Corporation has developed a new small diameter pump for purging and sampling ground water from small-diameter (2-inch) monitoring wells. Blasland, Bouck & Lee, in conjunction with the University of Waterloo Centre for Groundwater Research ran a series of tests on the pump under controlled (laboratory) conditions to evaluate the ability of the pump to deliver "representative" ground-water samples. The performance of the pump was also evaluated under field operating conditions to examine its effectiveness for purging as well as sampling monitoring wells and its long term reliability.

Laboratory test results indicate that the pumping rates can be effectively varied from rates as low as 0.1 liter per minute to rates in excess of 30 liters per minute at pumping levels between 6 to 30 meters. Special laboratory mixtures of water with specific concentrations of organic and inorganic compounds were created to determine the pump's ability to deliver "representative" samples.

Test results indicate that there were no statistically significant losses in the low and high concentration organic solutions for the compounds Methane, 1,1-DCE, t-1,2-DCE, Benzene, TCE and Toluene. There were no statistically significant changes in the concentrations of inorganic compounds. Based on comparative data with most commonly used mechanical sampling devices, the Grundfos pump equals or exceeds their ability to provide representative samples for organic and inorganic chemical analyses.

Field testing verified the practicality of using the pump for purging and sampling. The pump was also found to be able to pump water with considerable turbidity without experiencing operation difficulties.

The Grundfos small-diameter ground-water sampling pump offers the ability to deliver "representative" samples of water from two-inch monitoring wells, throughout a broad range of depth. It also offers the flexibility of being able to purge water at flow rates in excess of 30 liters per minute during the process of preparing the well for sampling in a reasonable length of time.

Introduction

Grundfos Pumps Corporation (Grundfos) contracted Blasland, Bouck & Lee in July 1989 to conduct a series of performance tests on a new small-diameter pump (MP1 Redi-Flow 2-inch Environmental Submersible Pump) developed by Grundfos for the purpose of purging and sampling ground water from ground-water monitoring wells. Blasland, Bouck & Lee subcontracted with the University of Waterloo Centre for Groundwater Research (Waterloo) to run a series of tests on the pump under controlled conditions and provide a scientific, unbiased evaluation of the ability of the pump to deliver a "representative" sample. This evaluation was designed specifically to determine whether or not the new Grundfos pump could compete in the existing ground-water sampling market as a purging and sampling pump.

Blasland, Bouck & Lee staff also conducted a field evaluation of the new Grundfos pump to provide information on the pump's operational characteristics. This evaluation was designed specifically to determine the pump's ease of operation, maintenance, and decontamination under actual field conditions, and to identify any operational difficulties or design flaws that should be corrected prior to marketing the pump for ground-water purging and sampling applications.

Experimental Design and Test Method

An artificial "well" was installed in a stairwell at Waterloo. The well consisted of a 15.24-centimeter diameter stainless steel tube, 10 meters high, with a control sampling port near its bottom. The well was filled and drained at the bottom with an air-driven pump connected to a stainless steel reservoir.

The organic compounds used in the evaluation were:

Compound	Henry's Constant
methane	67.4
1,1-dichloroethene (1,1-DCE)	15.6
trans-1,2-dichloroethene (t-1,2-DEC)	0.669
benzene	0.550
trichloroethene (TCE)	0.915
toluene	0.670

The organics (except for methane) were introduced into the system by injecting and mixing a methanolic stock solution below the surface of the water in the reservoir, prior to being pumped up the column. Inorganic constituents, including sulfate, nitrate, arsenic, chromium, and iron were added in a similar manner.

Three separate pumping experiments were conducted at flow rates of 0.1 liters per minute (l/m). This is the flow rate that U.S. EPA recommends for sampling ground water with volatile organic compounds (VOCs). The first experiment involved water containing 20 ppb of VOCs (low loading). The second experiment involved using water with a VOC concentration of 200 ppb (high loading). The third experiment involved examination of the influence of the pump on the inorganic chemicals listed above.

The experiments entailed pumping 60 liters of organic-spiked or inorganic-spiked water into the column and simultaneously collecting five pumped and five control samples, in duplicate, in 60-ml hypo-vials for organic analyses and 100 ml polyethylene bottles for inorganics analyses for each set of conditions. The pumping lift was approximately 20 feet.

Pre- and post-test "in-line" parameters were obtained for all of the experiments. These consisted of measuring pH, temperature, and conductivity at the control port and the pump outlet before and after sample collection.

Each set of organic samples (i.e., from one sampler) was randomized and split in two; five for the methane determinations, five for the other organics (or in the case of the control experiment, three and three). Samples from a given experiment were always randomized for analysis and run in one session. Methane determinations were done using

GC/FID (static headspace injection). The organic solvents were determined by GC/PID (static headspace injection). Inorganic analyses were performed following approved EPA methods.. Syringe blanks and external standards were run periodically to maintain data quality.

The method detection limits for the various organic parameters were:

Compound	Detection Limit (ppb)
methane	0.22
1,1-DCE	0.14
trans-1,2-DCE	0.20
benzene	0.26
trichloroethylene	0.58
toluene	0.56

Test Results

Data were tabulated and the means and relative standard deviations calculated for each set of five values. The SYSTAT statistical package was used to obtain box plots and perform Bartlett's tests, analyses of variance, and t-tests, where applicable. Statistical outliers found in the box plots and values below detection levels (for inorganic compounds) were discarded. A confidence interval of 95 percent was used throughout.

In the first experiment, at a low concentration of organic compounds (20 ppb), there were no statistically significant differences between samples from the pump and the control samples for the compounds analyzed. Likewise, in the second experiment at high concentrations of organic compounds (200 ppb), there were no statistically significant differences between the samples from the pump and the control samples for the compounds analyzed. There were also no statistically significant difference observed for inorganic compounds for the pump samples and control samples in experiment number 3.

Tables 1 through 3 contain the actual test data for each of the experiments. Pump sample data are compared to control sample data as a function of percent recovery for each compound in Figures 1 through 3. The figures more readily present an impartial comparison of the pump and control data for specific compounds. It should also be noted that for the volatile organic compounds there was no perceived relationships observed between compound volatility and the percent recovery of the compound.

Field Evaluation of Pump Performance

Blasland, Bouck & Lee conducted limited testing of the Grundfos pump to evaluate pump performance in the field. Specifically, Blasland, Bouck & Lee attempted to determine the following:

- the effect of varying pump depth on pump discharge rates;
- the ability of the device to pump silt-laden ground water; and
- general pump operational characteristics.

Geologic environments in which the pump was used included bedrock wells completed in limestone and fractured sandstone, and screened wells completed in clay-rich glacial till and sandy alluvial aquifers. Well depths varied from 15 to 120 feet and well diameters varied from 2 to 4 inches.

Operation of the Pump

There are two primary components to the Grundfos pump system. The MP1 Environmental Submersible Pump and the BT1/MP1 Converter. Both the pump and converter are compact and relatively light, 5.5 pounds and 25 pounds, respectively. Used in a portable operating mode, a two-person crew can conveniently manage a multiple well sampling operation. If the MP1 is dedicated to each well, then one person could operate the system assuming an appropriate power source is readily available.

The pump is constructed primarily of 316 stainless and teflon components. Overall length of the pump is 287 millimeters (mm) or 11.30 inches. Maximum pump diameter is 46 mm or 1.81 inches. The dimensions of the converter are 228.6 mm (9 inches) by 355.6 mm (14 inches) by 469.9 mm (18.5 inches).

The system requires a single-phase, 230 volt source of electricity. In remote locations, where an appropriate power source is not available, a properly sized portable generator is required. When using a portable generator, a two-person sampling crew will be required.

Normal procedures require the placement of the pump down to the desired depth in the well. Note that pump power leads are available in 3.62-meters (25-foot) increments of length. The unit is then attached to its power source and turned on at the converter. A dial on the converter permits adjustment of the pump frequency, allowing the operator to increase or decrease the flow rate within the operating limits of the pump for a given amount of total hydraulic head (pumping lift).

Pump Performance

Field evaluations of the Grundfos "MP1 Redi-Flow 2" Environmental Sampling Pump were performed by Blasland, Bouck & Lee staff from the Syracuse and Columbus offices. Staff members using the pump evaluated its performance in terms of flexibility for purging and sampling the well, ease of decontamination and maintenance, and overall reliability.

Initial attempts to use the pump at low sampling rates (0.1 l/min) were not achieved due to confusion over proper operation of the pump. Much of this confusion was due to the absence of a detailed operating manual during the early sampling attempts. Subsequent direction from Grundfos enabled the sampling teams to obtain flow rates as low as 0.1 l/min.

The pump was tested in deep bedrock wells, and shallow and deep wells in unconsolidated materials. The Syracuse office staff routinely used the pump to perform well development, as well as purging and sampling. At no time did silt or clay size particles suspended in the well water significantly impact the performance of the pump.

Well purging rates ranged from 31 l/min (8.2 gpm) in a well with a pumping level of about 12 feet to 24 l/min (6.3 gpm) with a pumping level of 110 feet. Sampling rates ranged from less than 0.1 l/min to over 0.2 l/min. The ability to achieve 0.1 l/min increased with the operator's familiarity with the equipment. Eventually, all operators were capable of obtaining the 0.1 l/min flow rate for both shallow and deep pumping levels.

The pump proved to be extremely reliable in the field. Its capability to discharge turbid samples enabled field crews to use it in the well development process. The pump was never used, however, to pump water with significant amounts of sand. Discharge under positive pressure made in-line filtration convenient.

The ability to purge wells at rates greater than 20 l/min (6 gpm) and then reduce flow to 0.1 l/min makes the pump ideal for ground water sampling. This is especially true where ground-water has to be purged from deep wells or large diameter wells prior to sampling. Of the pumps designed to fit into 2-inch diameter monitoring wells, the Grundfos pump's ability to purge at flow rates as high as 30 l/min and sample at the recommended flow rate of 0.1 l/min offers an advantage not yet otherwise achieved by other commonly available pumps. The combination of stainless steel and teflon construction materials also reduces the likelihood that the pump would impact ground-water quality samples.

The use of dedicated discharge tubing expedites the decontamination process. In general, the pump exterior can be cleaned by mild detergent and/or solvent followed by a distilled water rinse. Detergent

and/or solvent followed by distilled water can be flushed readily through the interior of the pump by operating the pump in a bucket containing the appropriate solution. The pump can also be readily dissembled in the field for more rigorous cleaning or repair.

Conclusions

From the laboratory and field testing of the Grundfos pump conducted by the project team, several conclusions can be drawn regarding the overall performance of the pump.

1. Based on controlled laboratory testing of the pump at flow rates of 0.1 l/min, there were no observed statistically significant differences between the control data and the data for the Grundfos MP1 pump during the three experiments.

2. Purge rates as high as 31 liters per minute could be achieved. Purge rates varied with depth of water in the well, but generally were found to range from 20 liters per minute to 30 liters per minute.

3. Flow rates for sampling purposes can be reduced to 0.10 l/min (0.026 gpm) for sensitive parameters such as volatile organic compound (VOCs) and selected metals. This pumping rate achieves U.S. EPA's recommended sampling rate for VOCs.

4. The pump was found to operate equally well in 4-inch and 2-inch diameter wells.

5. Clay, silt, and fine sand seemed to have had no effect on the pump. The experience of the Blasland, Bouck & Lee personnel using the pump in silty wells indicate that the pump can operate up to 40 minutes while purging silty water.

6. The ability to achieve high flow rates makes the pump a more practical tool for sampling since the combination of reasonable purge rates and controlled low flow rates expedite operations for ground-water monitoring programs.

7. The pump can be used as a portable sampling device or as a dedicated sampling device.

TABLE 1

RESULT OF TEST
FOR LOW VOC LOADING
AT FLOW RATE OF 0.1 l/min

Sample	Methane	1,1-DCE	t-1,2-DCE	Benzene	TCE
Control 1	0.259	2.22	2.49	3.18	5.15
Control 2	0.244	2.05	2.18	3.07	4.75
Control 3	0.248	2.10	2.09	2.95	4.65
Control 4	0.252	2.27	2.43	3.31	5.50
Control 5	0.240	2.45	2.19	2.89	4.70
AVG	0.249	2.22	2.28	3.08	4.95
N	5	5	5	5	5
VAR	0.0000	0.02	0.03	0.03	0.13
STD	0.007	0.16	0.17	0.17	0.36
Grund 1	0.232	2.12	2.00	2.82	4.33
Grund 2	0.244	1.46	1.65	2.32	3.38
Grund 3	0.254	2.73	2.72	3.51	5.22
Grund 4	0.244	2.34	2.15	3.10	4.85
Grund 5	0.244	2.56	2.22	3.08	4.30
AVG	0.244	2.24	2.15	2.97	4.41
N	5	5	5	5	5
VAR	0.000	0.25	0.15	0.19	0.48
STD	0.008	0.50	0.39	0.44	0.69
			PERCENT OF RECOVERY		
	97.99	101.02	94.4	96.36	89.19

TABLE 2

RESULT OF TEST
HIGH VOC CONCENTRATION
AT FLOW RATE OF 0.1 l/min

Sample	CH4	1,1-DCE	t-1,2-DCE	Benzene	TCE	Toluene
Control 1	0.934	22.71	22.25	33.27	53.92	67.57
Control 2	1.005	26.98	27.11	38.69	62.74	78.27
Control 3	0.994	27.29	27.33	37.05	-	75.01
Control 4	0.970	27.18	27.68	41.87	64.76	82.58
Control 5	0.982	28.28	30.83	41.73	69.80	77.47
AVG	0.977	26.49	27.04	38.52	62.81	76.18
N	5	5	5	5	4	5
VAR	0.001	4.71	9.45	12.82	43.90	30.62
STD	0.027	2.17	3.07	3.58	6.63	5.53
Grund 1	0.978	27.74	30.65	39.06	67.21	82.77
Grund 2	0.974	24.95	26.52	37.05	61.87	70.90
Grund 3	0.942	24.73	25.65	38.24	60.24	74.99
Grund 4	0.974	29.21	29.81	40.74	68.41	79.90
Grund 5	1.014	25.14	25.08	36.60	57.60	76.55
AVG	0.976	26.35	27.54	38.34	63.07	77.02
N	5	5	5	5	5	5
VAR	0.001	4.04	6.37	2.75	21.26	20.79
STD	0.026	2.01	2.52	1.66	4.61	4.56
			PERCENT OF RECOVERY			
	99.94	99.49	101.86	99.52	100.42	101.11

TABLE 3

RESULT OF TEST
INORGANIC COMPOUND DATA
AT FLOW RATE OF 0.1 l/min

Sample	Total Iron	Total Chromium	Sulfate	NO3/NO4
Control 1	<0.05	0.23	44	2.7
Control 2	0.06	0.23	56	3.0
Control 3	<0.05	0.23	61	2.9
Control 4	0.05	0.21	49	2.9
Control 5	<0.05	0.22	44	3.0
Grund 1	<0.05	0.23	56	2.9
Grund 2	<0.05	0.22	46	3.0
Grund 3	<0.05	0.22	57	2.9
Grund 4	0.06	0.21	44	3.0
Grund 5	0.05	0.22	53	2.9
			PERCENT OF RECOVERY	
	100	98.2	100.7	100

FIGURE 1

RESULTS OF TEST/LOW VOC LOADING AT FLOW RATE OF 0.1 l/min

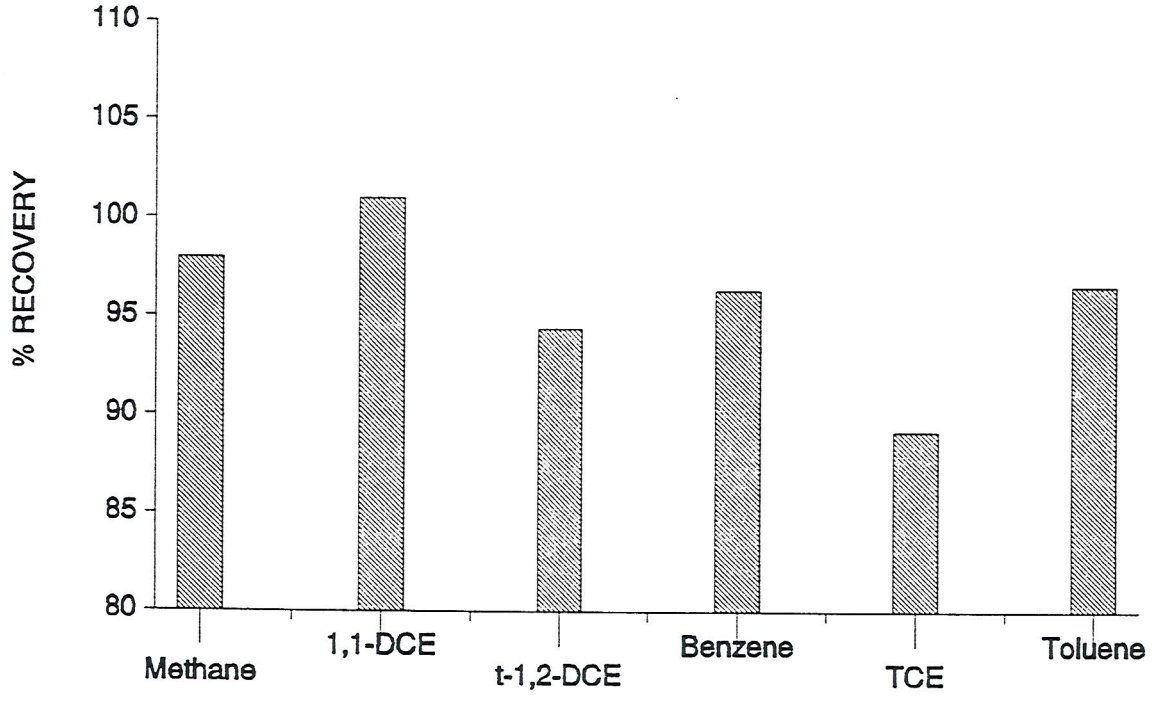

FIGURE 2

RESULTS OF TEST/HIGH VOC CONCENTRACTION AT FLOW RATE OF 0.1 l/min

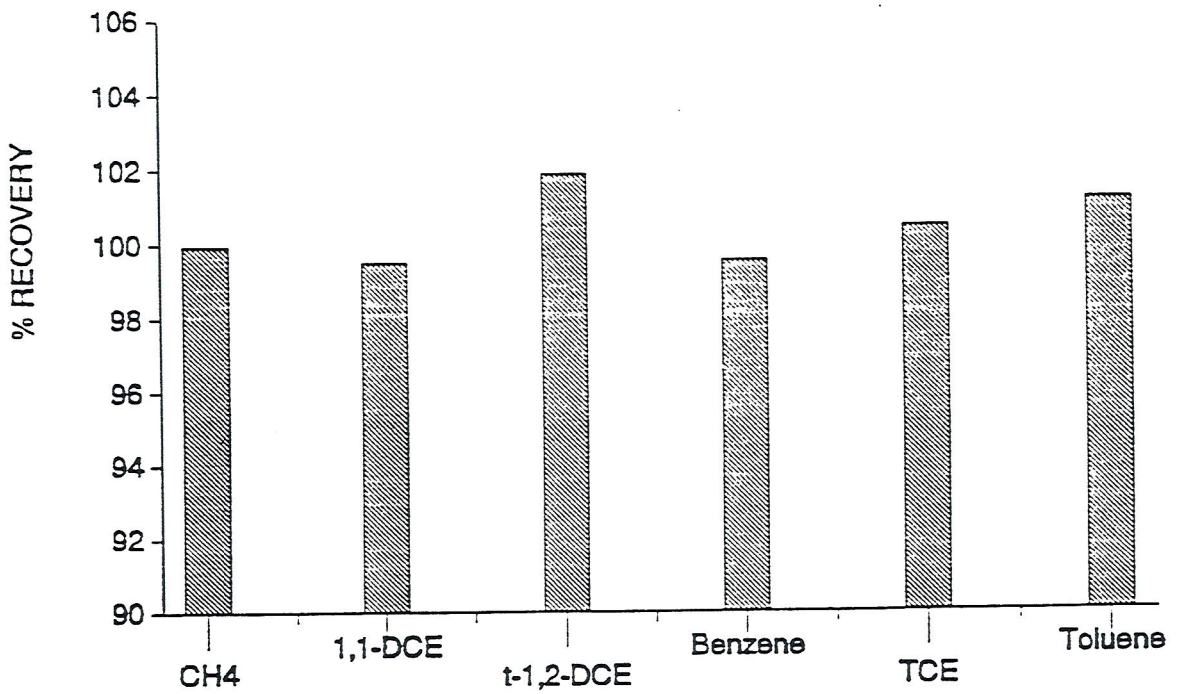

FIGURE 3

RESULTS OF TEST/INORGANIC COMPOUND DATA AT FLOW RATE OF 0.1 l/min