Coopmans, E. J. A., Schwarz, H. P. & Pryor, M. J. (2001): The dewatering of a mining sludge containing hexavalent chromium using a tubular filter press. – Water Sci. Technol., 44 (1 5/6): 371-376, 5 Abb., 2 Tab.; Oxford.

The dewatering of a mining sludge containing hexavalent chromium using a tubular filter press – a South African development

E.J.A. Coopmans*, H.P. Schwarz* and M.J. Pryor**

* Explochem Water, PO Box 400, Ferndale, South Africa, 2160. E-mail: *maniec@explochem.co.za*

** Process Evaluation Facility, Umgeni Water, P O Box 9, Pietermaritzburg, 3200.
E-mail: *martin.pryor@umgeni.co.za*

Abstract A chromium smelting process can result, under oxidising conditions, in the production of a dust which when slurried and pumped to a waste dump heap is likely to pollute the environment. South Africa is a large producer of chromium metal and the problem of the release of hexavalent chromium (Cr^{6+}) to the environment is a serious concern. The department of Water Affairs and Forestry in South Africa monitors all environmental discharges and regulate the levels of toxic chemicals and pollutants. The "Tubular Filter Press" a South African developed sludge dewatering system was proposed for the recovery of dust in this effluent. The filter press was operated for the dewatering of waterworks sludges and promises to be successful for this application. A single tube pilot study shows that chromium discharge to the environment can be eliminated. Feed solids concentrations of between 40 and 50 g/l were fed to the tubular filter resulting in cake solids concentrations in excess of 50%. The operating pressure of the system was between 200 and 300 kPa and the flux reduced to 200 $L/m^2.h$ during the filtration cycle. The filtration was modelled using a variable pressure, internal cylindrical compressible cake filtration model and operating parameters for a full scale plant were proposed.

Keywords Microfiltration; pressure filtration; compressible solids dewatering

Water Science and Technology: Water Supply **Vol 1 No 5/6 pp 371–376**

Introduction

South Africa is a water scarce country with an average rainfall of 500 mm per annum, where twenty-one per cent of the country receives less than 200 mm and as such all effluent has to be purified and returned to the rivers. Industry utilises a large proportion of the water available, of which most is returned to the environment after limited effluent treatment.

During the treatment of potable water, waterworks sludges are normally thickened before dewatering using centrifugation. The development of the "Tubular Filter Press" started in the mid 1980s when it was shown (Rencken, 1992) that solids could be dewatered. The first filter press was installed by Umgeni Water in 1987 (which comprised horizontal tubes woven in the form of a microfiltration fabric curtain), but further development was required. During the development, significant changes were made whereby the operation of the plant would become more reliable. The size of the tubes was increased from 25 mm to 60 mm and the orientation of the tubes was changed from horizontal in the previous design to vertical in the new design. At the same time a flushing procedure was developed, and the process patented for easy removal of dewatered solids.

Following successful small scale trials, the construction of the first vertical configuration tubular filter press was completed in 1995 (Figure 1). The filter press successfully dewatered sludge comprising solids concentrations between 7 g/L and 30 g/L (0.7% and 3.0% m/v) producing a filter cake between 20% and 33% solids (m/m) at solids recoveries up to 75% (Pryor and Mullan,1998).

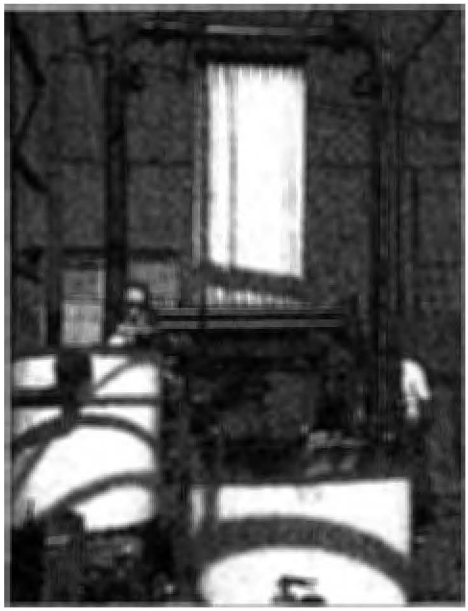

Figure 1 Vertical tubular filter for waterworks solids dewatering

The use of pressure filtration for solids dewatering is commonly used and has been shown to produce higher cake solids concentrations than centrifuges and may be more cost effective due to lower predicted power consumption. The need to replace curtains on an infrequent basis will however be required, but as the system is modular this process is envisaged to be ideal to meet the needs of small industries and small waterworks.

Background and objectives

A large chromium sintering operation in South Africa produces a dust effluent which is collected in water and pumped to a slimes dam. The pollution of a water system was identified and the reduction of chromium and dewatering of the effluent was proposed.

Two possible treatment methods were considered to reduce Cr^{6+} to Cr^{3+}.

Ferrous sulphate reduction

$$2CrO_3 + 6\,FeSO_4.7H_2O + 6H_2SO_4 \rightarrow Cr_2(SO_4)_3 + 3Fe_2(SO_4)_3 + 48H_2O$$

Sodium hydrosulphite reduction

$$2CrO_3 + 3Na_2SO_3 + 3H_2SO_4 \rightarrow Cr_2(SO_4)_3 + 3Na_2SO_4 + 3H_2O$$

A second step is then possible to remove the chromium from solution by the addition of caustic to form a metal hydroxide.

$$Cr_2(SO_4)_3 + 6NaOH \rightarrow 2Cr(OH)_3 + 3Na_2SO_4$$

The latter method was recommended as it is more cost effective, and also because the ferrous sulphate method results in the formation of ferrous hydroxide which subsequently increases the mass of solids requiring dewatering.

Pilot scale solids dewatering

A single vertical tube pilot plant comprises a feed tank for the effluent, a permeate collection tank and a single woven fabric tube, Figure 2 (60 mm tube diameter) was used to investigate the dewatering characteristics of the effluent.

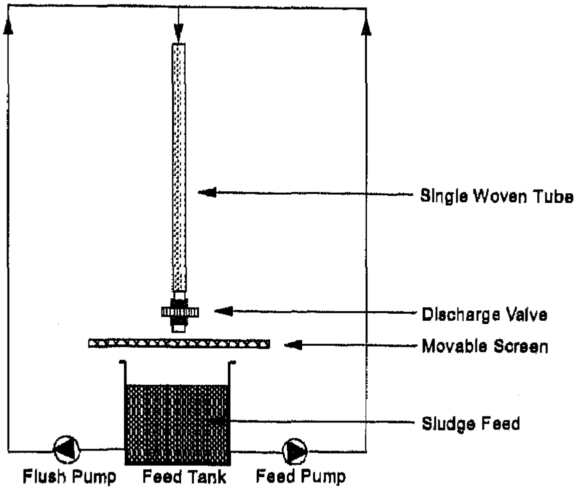

Figure 2 Single tube pilot plant

Filtration

A metering pump (feed pump) pumps sludge from the feed tank into the top of a single tube, suspended vertically above the feed tank. A discharge valve on the bottom end of the tube, when closed during the filtration cycle, allows the pressure to build up inside the tube and filtration through the woven fabric is achieved. The pressure in the tube increases and is controlled at the operating pressure. The permeate resulting from filtration through the woven fabric is collected in a collection trough attached to the bottom of the woven tube, and is directed into the permeate tank. Filtration continues until either the flux reduction is excessive, the filtration time is exceeded or until the amount of solids pumped into the tube exceeds an amount which is likely to block the tube.

Flushing

A centrifugal pump is provided to assist with the removal of solids from the tube when the discharge valve is opened during the flush cycle. Feed sludge is used as a flushing fluid. The flow rate is measured and can be regulated to optimise the flushing velocity through the tube. Solids are discharged from the bottom of the tube onto a screen/conveyor and removed from the filter.

Process parameters

The feed solids concentration and pressure of filtration are the main process parameters which affect the length of a filter run and the concentration of the cake solids concentration.

The objectives of the investigation were to

- Obtain reliable pilot plant data using a single tube
- Use this data to predict the operation of the full scale plant under different operating conditions
- Make recommendations for the final operation of the full scale plant

During each experiment the initial feed solids concentration was measured and the volume filtered was recorded vs. time. Final solids concentrations of the sludge and the filter cake were measured to complete a mass balance.

The best experiments (with respect to the mass balance) were chosen and used for the modeling exercise. These are summarised in Table 1.

Table 1 Summary of single tube pilot plant tests

	Pressure (kPa)	Feed solids conc. (g/L)	Inal filtrate Fvolume (L)	Filtration cycle run time (min)	Final filtrate flux (L/m2/hr)	Final cake conc. (%)
Run 7	200	45.7	25.2	10.5	271	50.8
Run 8	200	44.7	26.1	13	172	51.9
Run 9	250	43.4	34.2	14	198	53.6
Run 10	250	42.0	36.3	15 1	94	53.3
Run 11	300	41.4	31.2	11.5	269	53.6
Run 12	300	47.5	27.6	11	233	54.4
Run 13	300	47.5	32.6	13.5	206	56.2
Run 14	300	45.9	38.3	17	178	55.4

The filtration is classed as constant pressure, but during the initial period whilst the tube is filling the pressure is not constant. Figure 3 shows an initial slow rate filtration followed by a typical constant pressure – declining rate filtration profile. This creates problems in modelling the dewatering as the filtration times are typically short (in the region of 10–15 minutes).

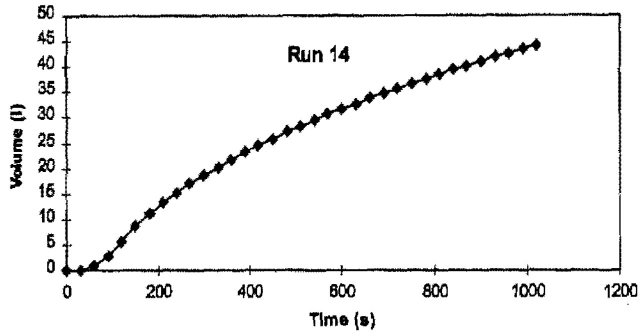

Figure 3 Volume filtered vs time for Run 14 @ 300 kPa

Modeling of single tube pilot plant operation

A model of internal cylindrical constant pressure filtration was developed (Rencken, 1992), and has been compiled into a computer package comprising two parts (Mullan, 2000). Data obtained from batch planar filtration tests, from settling tests and from pilot plant trials can be used to regress for parameters which describe the properties of the compressed solids during filtration. An integration section of the program then uses the calculated parameters to predict the operation of the filter.

The data from all the runs (at different pressures) was used to determine the sludge parameters. During the integration however, a constant pressure profile was found not to accurately predict the filtration performance. An assumed variable pressure profile can be used to more accurately predict the actual performance (Figures 4 and 5). When a reduced pressure is specified during the initial part of the filter operation the prediction is much closer to the actual data.

During the integration the cake thickness is calculated. This is useful to be able to select an operating region where the risk of blocking tubes is minimised.

Prediction of full-scale plant performance

The operation of the filter was then modelled at different feed solids concentrations to predict the sensitivity of the process to changes in feed solids. The criterion by which the process should be operated is governed by the cake thickness i.e not exceeding 10 mm (one-third the radius of the tube) to allow sufficient tube volume for effective cleaning and removal of the cake after filtration.

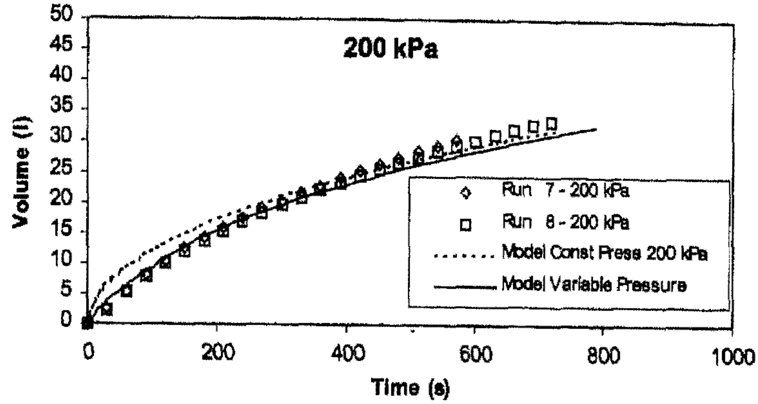

Figure 4 Model prediction at 200 kPa

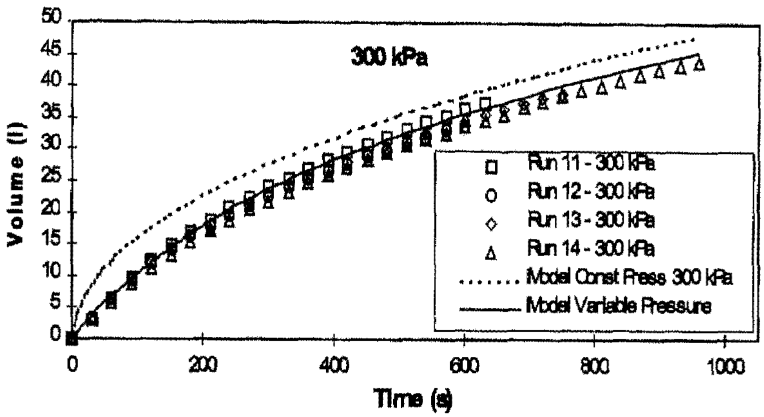

Figure 5 Model prediction at 300 kPa

Prediction of cake thickness after different filtration times (Table 2) show that when operating with a lower feed solids concentration the plant can safely be operated for up to 20 minutes at 400 kPa, but should not be operated longer than 10 minutes when the feed concentration increases to 80 g/l.

Conclusions

The following recommendations were made following this study

- Chromium reduction is essential to prevent discharge to the environment. This should be

Table 2 Cake thickness prediction feed solids concentrations of 45 g/L and 80 g/L

	Cake thickness (mm)					
	Feed solids 45 g/L			Feed solids 80 g/L		
	200 kPa	300 kPa	400 kPa	200 kPa	300 kPa	400 kPa
5	4.1	4.6	5.2	5.1	5.9	6.4
10	6.0	6.7	7.0	7.3	8.4	9.1
15	7.4	8.3	9.3	9.0	10.3	11.3
20	8.6	9.7	10.7	10.5	11.9	12.9
22	9.1	10.2	11.2			
24	9.5	10.7	11.7			
26	9.9	11.1	12.3			
28	10.3	11.6	12.8			
30	10.6	11.9	13.2			

performed using sodium hydrosulphite or alternatively ferrous sulphate. At least the stochiometric amount should be used but preferably a slight excess should be considered.

- The tubular filter press is capable of dewatering the effluent and producing a cake solids concentration in excess of 50% (m/m). To achieve this a pressure of up to 400kPa should be reasonable. but at higher feed solids concentrations the operating pressure should be reduced.

References

Mullan. D.J. (2000). Modelling of the Tubular Filter Press Process. MSc (Chemical Engineering). University of Natal. Durban.

Pryor. M.J., Mullan. D.J. (1998). The Development of an Exxpress Unit for the Dewatering of Waterworks Sludges and the Production of Potable Water. Water Research Commission of South Africa. Report No 568/1/98.

Rencken. G.E. (1992). Performance Studies of the Tubular Filter Press. PhD (Chemical Engineering). University of Natal. Durban.