Effect of water quality in freeness testing

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ABSTRACT: The ISO standards on the drainability tests on pulp require the use of distilled or deionized water throughout the test. However, some anomalies have been noticed, which originate from the fact that purified water is extremely sensitive to even small amounts of electrolytes that may dissolve from the sample during the test. To study the subject, several kinds of pulp and waters with different electrical conductivity were used in SR tests. The effect of water quality on beating and sheet forming was also studied. The results showed that the increase in water conductivity at the lower range has a remarkable decreasing effect on the SR number. Little difference exists among the test results with waters at the same electrical conductivity but containing different soluble salts. Finally, the effect of water quality on beating and sheet forming is negligible.

KEYWORDS: Schopper Riegler freeness, test methods, water quality.

It is well known that the quality of water used in drainability tests (SR, Schopper-Riegler, or freeness) has a considerable influence on the test results *(1, 2)*. To avoid this, the standard methods (ISO 5267/1 and ISO 5267/2) require the use of distilled or deionized water in these tests. This use is recommended also for the laboratory beating methods described in ISO 5264/1, 5264/2, and 5264/3.

In recent years, however, studies carried out in Finland and Norway suggest that instead of distilled water, water with an electrical conductivity above 15 mS/m should be used in SR and freeness tests *(3, 4)*. The ISO secretariat found the question of water quality to be so important that it suggested further studies be undertaken.

This further study on the effect of water quality in physical pulp testing has been conducted by the Pulp and Paper Research Laboratory, Tianjin Institute of Light Industry, People's Republic of China. The results obtained are reported in this paper.

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Effect of water quality on the SR test of different pulps

Different pulps, such as bleached and unbleached wood pulps, nonwood pulps, sulfate, and sulfite pulps, were used for studying the effect of water quality on the SR test. The standard method described in ISO 5267/1 was followed during the SR test, with the exception of the water quality specified in this method.

Each pulp sample, corresponding to 30 g of ovendry pulp was soaked in 0.5 L of distilled water at room temperature for 15 h. The soaked pulp was torn into pieces, diluted with distilled water to a total volume of 2000 mL, and disintegrated for 10,000 revolutions in the standard disintegrator. The disintegrated pulp suspension was thickened to a consistency of 10%, after which the thickened pulp was beaten with a PFI mill according to ISO 5264/2. The beaten pulp was diluted with distilled water to 1.5% consistency and disintegrated for 10,000 revolutions, then diluted again with distilled water to a total volume of 8000 mL. A diluted pulp suspension corresponding to 2 g of ovendry pulp was taken out. Waters with different electrical conductivities were added into each pulp suspension, respectively, to a total volume of 1000 mL. The SR number was tested at 20°C. The electrical conductivity of the filtrate of the SR test was determined. The five kinds of water used in this experiment are as follows:

Water conductivity, mS/m	*Electrical*
Distilled water	0.20
Distilled water with tap water	6.9
Tap water	52
Tap water with a small amount of NaCl	150
Tap water with a large amount of NaCl	900

The results are given in **Fig. 1.**

Figure 1 shows that, for all these pulps, the SR numbers tested decreased rapidly with increase of filtrate conductivity in the lower range (below 20 mS/m). For example, the SR number of bleached softwood sulfite pulp decreased from 52 to 36 as the conductivity of the filtrate increased from 0.3 mS/m to 22 mS/m. Even though the bleached reed sulfite pulp contained more soluble salts, the SR number of this pulp decreased from 50 to 45 when the conductivity of the filtrate increased from 1.85 mS/m to 24 mS/m. However, if the conductivity of the filtrate was above the value of about 20 mS/m, the further increase of filtrate conductivity had only little effect on the SR number.

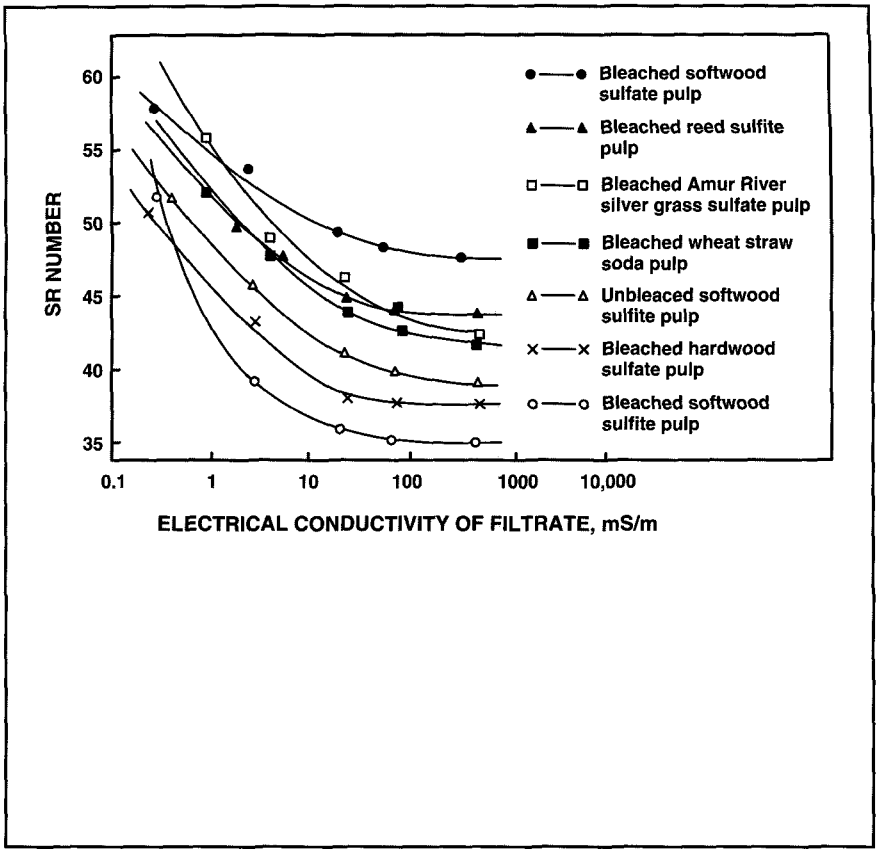
It is also found that although the conductivity of the distilled water used is 0.2 mS/m, the conductivity of the filtrate varies from 0.24 mS/m (for bleached hardwood sulfate pulp) to 1.85 mS/m (for bleached reed sulfite pulp). Just in this range, the SR test is affected considerably. In this case, the comparison of pulps at certain SR levels is unreliable. But this effect can be diminished by using water with higher electrical conductivity (above 20 mS/m) in the SR test.

The electrical conductivities of several kinds of water taken from different areas in the People's Republic of China are listed in **Table I.** It is obvious that, in most cases, tap water may be used for the SR test instead of distilled water.

Effect of water quality on the SR test of beaten pulps

Bleached softwood sulfite pulp was beaten at different revolutions in a PFI mill, so that the pulps with different SR numbers were obtained. Five kinds of water were used for the SR test, according the procedures given above.

1. Effect of water quality on the SR test of different pulps



I. Electrical conductivity of water

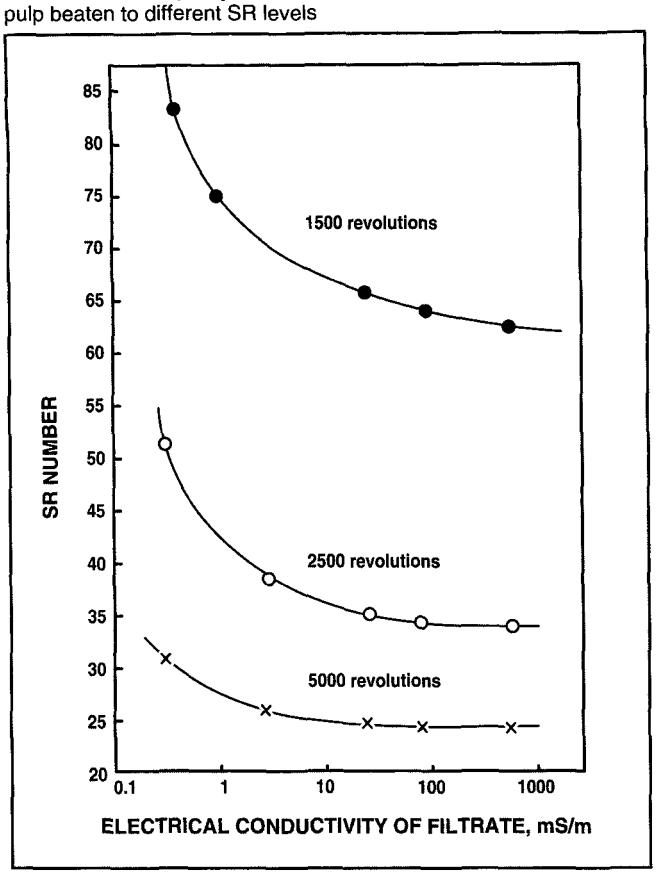
	Distilled water	*Tap water*	*Well water*	*River water*
Electrical conductivity, mS/m	0.20 1.12 2.62	43 52 89 63	129	74

It can be seen from **Fig. 2** that the SR numbers of all the beaten pulps decreased with increase of filtrate conductivity. This decrease in SR number became less significant when the conductivity of filtrate was above the value of about 20 mS/m.

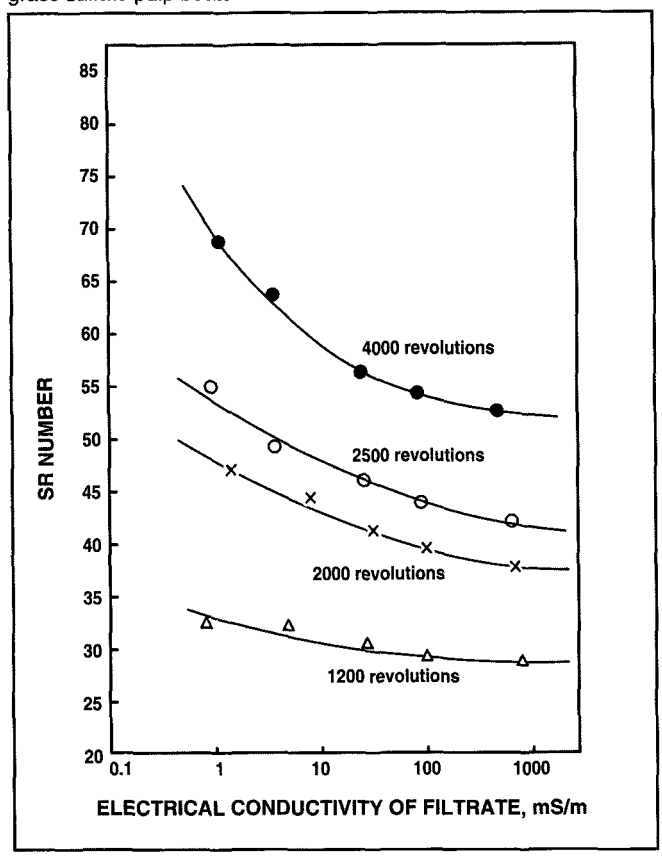
It was also found that at higher SR numbers, the effect of water quality on the SR test was more significant than at lower SR numbers. For example, when the pulp was beaten for 1500 revolutions, the SR number tested decreased from 31 to 25 as the filtrate conductivity was increased from 0.28 mS/m to 22 mS/m. However, when the pulp was beaten for 5000 revolutions, the SR number decreased from 83.5 to 66 as the filtrate conductivity was increased from 0.32 mS/m to 22 mS/m. The same was true of the bleached Amur River silver grass sulfate pulp shown in **Fig. 3.**

From the results obtained above, we conclude that water quality has a significant effect on the SR test. However, since tap water contains different kinds of electrolytes, it is difficult to say which electrolyte affects the test result. The principal ionic species found in the tap water used for the laboratory work are listed in **Table II.** To illustrate the strategy of electrolyte comparison, five kinds of soluble salts containing these ionic species were used for the SR test.

2. Effect of water quality on the SR test of bleached softwood sulfite pulp beaten to different SR levels



3. Effect of water quality on the SR test of bleached Amur River silver grass sulfate pulp beaten to different SR levels



II. Principal ionic species in tap water

	K^+	Na^+	Ca^{2+}	Mg^{2+}	HCO_3^-	CO^{2-}_3	SO^{2-}_4	Cl^-
Concentration, mg/L	3.1	20.1	46.1	12.2	144.0	4.8	34.6	24.0

III. Effect of different soluble salts in water on the SR test of bleached softwood sulfite pulp

	Water used for the SR test					
	Tap water	*Distilled water with $NaHCO_3$*	*Distilled water with $MgSO_4$*	*Distilled water with KCl*	*Distilled water with $CaCl_2$*	*Distilled water with NaCl*
Electrical conductivity of water, mS/m	52	52	52	52	52	52
SR	36	37.5	35	38	36	35
Electrical conductivity of filtrate, mS/m	22	22	26	23	24	22

As shown in **Table III**, there may be a slight difference among the SR numbers tested, because of differences in the kinds of electrolyte. The influence of the valency of the cation was less pronounced compared with the concentration of electrolyte.

Effect of water quality on beating

The standard method described in ISO 5264/2 was followed for the beating experiment except for the water quality specified in this method. Three pulp samples taken from the same bleached softwood sulfite pulp were soaked, disintegrated, thickened, and beaten for 2800 revolutions in the PFI mill. During these treatments, three kinds of water (distilled water, tap water, tap water with NaCl) were used, respectively, for the pulp samples. After beating, the three pulps were all diluted with tap water to 2000 mL, then disintegrated. The three disintegrated pulps were diluted again with tap water to a total volume of 8000 mL. For each pulp suspension prepared, a sample corresponding to 2 g of ovendry pulp was taken out. Tap water was added to the sample taken out to a total volume of 1000 mL, and the SR number was measured. The rest of each pulp suspension was used for sheet forming

according to ISO 5269/1. The physical properties were determined according to ISO 5270. The results obtained are listed in **Table IV**.

As shown in Table IV, although the three kinds of water used for beating had different electrical conductivities, the physical properties of handsheets are almost the same. That is, the strength levels of pulp did not change appreciably with the water used in the beating process.

IV. Effect of water quality on beating bleached softwood sulfite pulp

	Water used for beating		
	Distilled water	*Tap water*	*Tap water with NaCl*
Electrical conductivity of water, mS/m	1.2	47	470
SR	36	35	37
Electrical conductivity of filtrate, mS/m	46	48	54
Basis weight, g/m^2	64.81	65.68	63.07
Tensile index, N·m/g	66.4	67.8	69.4
Burst index, kPa·m^2/g	5.3	5.4	5.3
Tear index, mN·m^2/g	4.9	5.3	5.2

Effect of water quality on sheet forming

According to ISO 5264/2, a bleached softwood sulfite pulp was beaten in the PFI mill. Distilled water was used for the beating. The beaten pulp was disintegrated, then diluted with the distilled water to a total volume of 8000 mL. The SR number, measured by using distilled water, is 60.5. Comparative sheet forming was carried out by using three kinds of water (distilled water, tap water, and tap water with NaCl) according to ISO 5269/1. The physical properties of the pulp were measured according to ISO 5270. The results are listed in **Table V**.

V. Effect of water quality on sheet forming bleached softwood sulfite pulp

	Water used for forming		
	Distilled water	*Tap water*	*Tap water with NaCl*
Electrical conductivity of water, mS/m	0.2	52	360
Basis weight, g/m^2	64.18	64.70	64.45
Tensile index, N·m/g	70.2	70.5	70.2
Burst index, KPa·m^2/g	5.4	5.2	5.3
Tear index, mN·m^2/g	5.2	5.2	5.2

The results showed that the quality of water used in sheet forming had no effect on the strength properties, even though the drainage rate during the sheet forming was affected.

Conclusion

Electrolytes in water affect the SR test results of pulps significantly. The effect becomes less substantial when the electrical conductivity of testing water is above a given limit (about 20 mS/m).

Soluble salts from the pulp sample may affect considerably the SR test results obtained with distilled water. This effect can be diminished by the use of normal tap water or any other water with an electrical conductivity of more than 20 mS/m.

Cation species and valencies have only a minor effect on drainability compared with electrolyte consistency.

The results obtained also show that water quality has little effect on beating, sheet forming, and strength properties of pulps tested. TJ

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