Symposium on Capillary Waves and Gas Exchange, Trier 2-6. July 1979, H.-C. Broecker and L. Hase (eds.)
Berichte aus dem SFB 94 Meeresforschung, Univ. Hamburg, Heft 17, pp. 103-108 (1980)



doi: 10.5281/zenodo.10262

# The influence of surface tension on gas exchange; Measurements of gas exchange with alcohol/water mixtures in a circular wind-water tunnel

B. Jähne
Institut für Umweltphysik der Universität Heidelberg, W-Germany

U. Siegenthaler
Physikalisches Institut, Universität Bern, Switzerland

## 1. Possible influence of surface tension on gas exchange

The influence of surface tension on gas exchange can only be an indirect one. It is well known that capillary waves enhance gas exchange considerably (Kanwisher 1963, Jähne, Münnich and Siegenthaler 1979). Surface tension being the restoring force for capillary waves should therefore clearly influence gas exchange. Reduced surface tension changes the dispersion relation and influences wave amplitude as well as non-linear wave-wave interaction.

The use of liquids with surface tensions lower than that of water thus may be important for a better understanding of the enhancement of gas exchange by capillary waves.

One should clearly distinguish the effect of surface tension of a homogeneous liquid on gas exchange from those of surface films damping waves.

## 2. Gas exchange experiments with alcohol/water mixtures

In comparison to other liquids water has a high surface tension (72.8 dyn/cm at 20°C). Adding even small portions of alcohol to water will decrease surface tension of the mixture considerably (see fig. 1). In our experiments we used a mixture of 8% by weight of ethyl alcohol in water, resulting in a 30% lower surface tension and a slightly increased viscosity.

The experiments were carried out by U. Siegenthaler (University of Bern) working for 3 months in the Heidelberg wind-tunnel lab. Set up and measuring techniques are described in a recent publication (Jähne, Münnich and Siegenthaler 1979).

## 3. Results

### 3.1 Wave pattern

The annular water channel (10 cm depth, 10 cm width, 40 cm inner diameter) has the advantage to show a homogeneous wave pattern.

When using water for gas exchange experiments nearly no waves exist up to a wind speed of 8 m/sec, but then a sudden rise of rough waves occurs (Tschiersch and Jähne, 1979). The temperature independence of the critical wind speed for this sudden wave generation indicates that this cannot be explained by surface films, tearing at this wind speed. This effect seems rather to be a special property of circular systems with unlimited fetch (Francis (1949) observed similar wave characteristics in circular wind tunnels of different sizes) which might be interpreted as a Helmholtz-Kelwin instability (Jähne, Münnich and Siegenthaler, 1979).

When using an alcohol/water mixture, waves already commence at ~2.5 m/sec; and no further discontinuity in wave pattern is observed. The same effect occurs when the annular water channel is divided by a dam to simulate the limited fetch of linear wind-water tunnels. With our new optical wave measuring system we hope to quantify wave characteristics (first results: Tschiersch and Jähne, 1979).

### 3.2 Gas exchange

A comparison of gas exchange results obtained with water and a water/alcohol mixture is shown in fig. 2. With water in the undivided annular channel very low gas exchange rates are obtained, agreeing with theories for a smooth water surface (Jähne and Münnich, 1979, this issue).

With the sudden onset of waves gas exchange is enhanced considerably. Gas exchange rates for an alcohol/water mixture and water in the "divided" channel with similar wave characteristics show similar values at higher wind speeds. At lower speeds, however, higher rates (temperature dependent) are obtained with the alcohol/water mixture which may be caused by unstable stratification due to high evaporation cooling.

## 4. Discussion

Obviously the large difference of wave pattern and therefore gas exchange between water and a water/alcohol mixture in the undivided annular channel seems to be a special property of the circular system with unlimited fetch and influenced by centrifugal forces. But they indicate that the change of surface tension in linear wind-water tunnels and in nature will influence wave pattern as well as gas exchange.



## References

Francis, J.R.D. (1949) Laboratory Experiments on Wind-generated Waves, J. Mar. Res. 8, 120-131.

Jähne, B., Münnich, K.O. and Siegenthaler, U. (1979) Measurements of gas exchange and momentum transfer in a circular wind-water tunnel. Tellus 31, 321-329

Jähne, B. and Münnich, K.O. (1979) Momentum induced gas exchange through a smooth water surface, theories and experimental results from linear and circular wind-water tunnels (this issue).

Kanwisher, J. (1963) On the exchange of gases between the atmosphere and the sea. Deep-Sea Research 10, 195-207.

Tschiersch, J. and Jähne, B. (1979) Gas exchange through a rough water surface in a circular wind-tunnel; wave characteristics under limited and unlimited fetch. Preliminary results (this issue).

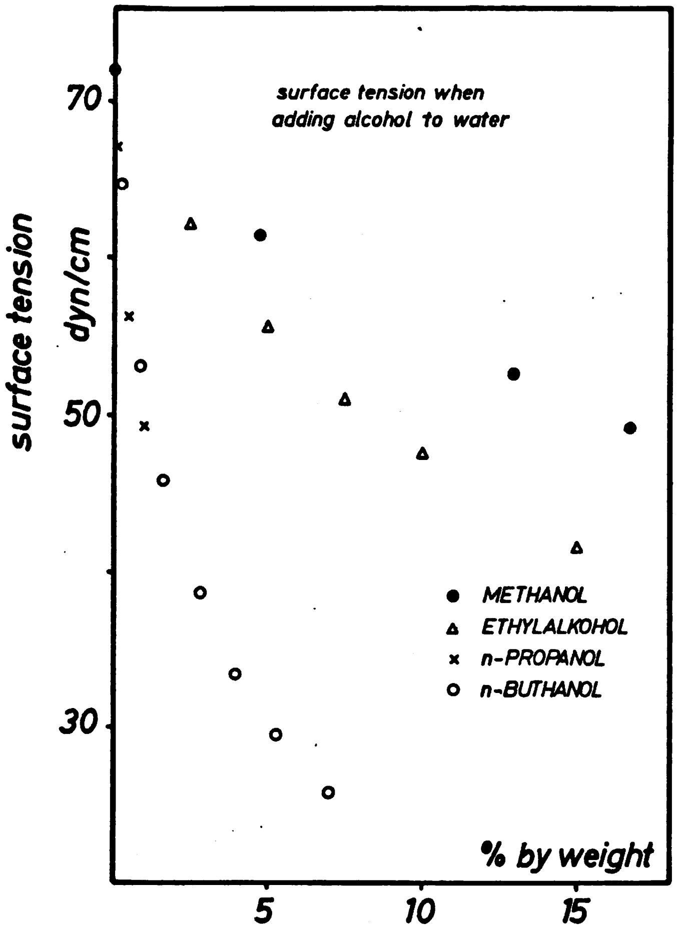


Fig. 1 : Surface tensions of alcohol/water mixtures.

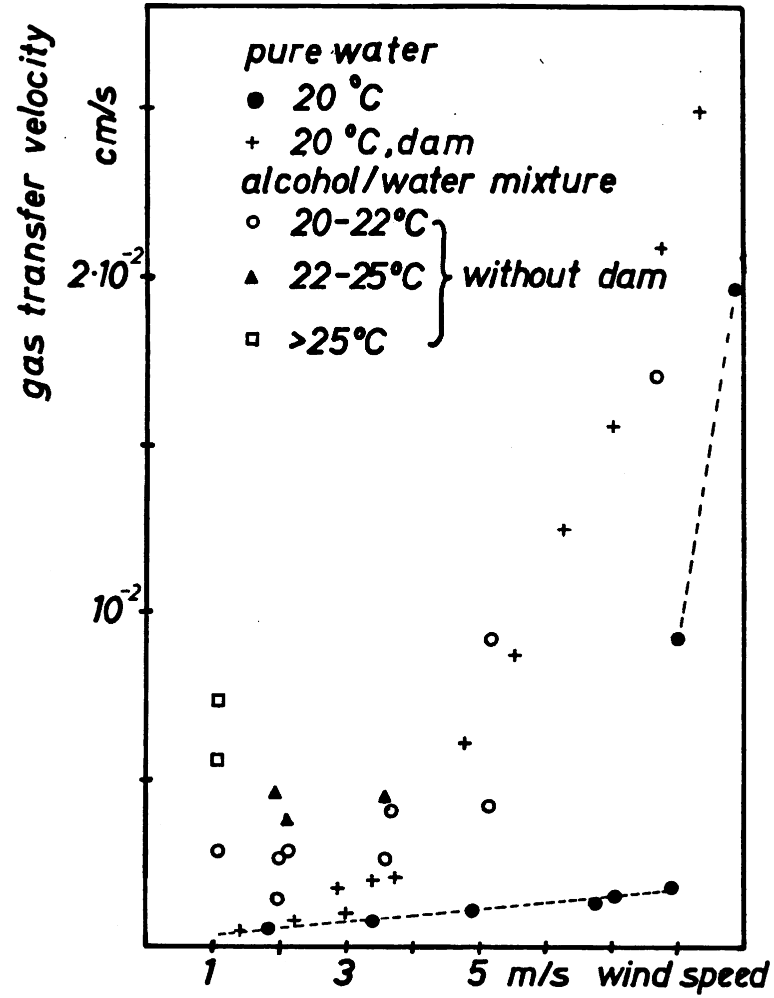


Fig. 2 : Gas exchange rates as a function of windspeed (at 10 cm height) in the small circular wind-water tunnel under different conditions as indicated in the figure.