Inaugural speech

Summary of me as a researcher.

The core focus of my research programme is on harmful algal blooms and associated freshwater quality of South African freshwater resources. The programme is built on four pillars namely: freshwater quality, algal assemblages, algal eco-physiology, and molecular ecology. Our current aim is to investigate effects of climate change (resulting in extended droughts/floods) on water quality, algal growth, and aquatic ecosystems. To address this national crisis through quality research that is also internationally acceptable.

Freshwater reservoirs and river are the major drinking water resources for South Africans as well as for general economic uses (e.g., agriculture, industry and hydroelectricity generation) and recreational activities. Algae and cyanobacteria occur naturally in source waters worldwide. However, certain species are known to form harmful blooms (Harding and Paxton, 2001), which can cause extensive problems in the drinking water treatment industry (Knappe et al., 2004; Meriluoto and Codd, 2005, Zoschke et al., 2011). Cyanobacteria (especially Microcystis sp.) are widely responsible for many water treatment problems due to their ability to produce organic compounds. These organic compounds include the cyanotoxin, microcystin (Conradie and Barnard, 2012), which can have an adverse effect on consumer health as well as taste and odour compounds (like geosmin and 2 methylisoborneol) that decrease consumer confidence in drinking water (Zoschke et al., 2011).

Pillar 1

The mass-occurrences of cyanobacterial and green algal in the nutrient enriched Vaal River as well as several South African impoundments such as the Hartbeespoort and Roodeplaat Dams have become notorious experiences every year. These bloom-forming cyanobacteria in particular the species Microcystis can produce hepatotoxins and toxic and non-toxic strains co-occur and are visually indistinguishable but can be identified and quantified molecularly in other words using their DNA. The financial and operational impact of these blooms on the drinking water industry is high as species produce bad tastes and odours and clogs filters.

Our research has shown that environmental conditions such as Water-surface temperature agree strongly with the toxin concentration, as well as the number of toxic gene copies present in the source water. This toxin production was associated with temperatures higher than 23 C. We observed that in some cases bloom forming cyanobacteria respond also morphologically/physically to environmental conditions such as nutrient concentrations and take on a form that will help them to survive better than others when conditions change. The cyanobacterium Oscillatoria's survival tactic when experiencing N or P limitation is to decrease its filaments length to disperse itself better throughout the water column.

In the case of the green algae Chlamydomonas it appeared to utilise a K-strategy in its growth, in other words it has a slower growth rate in optimal conditions while maintaining a higher growth rate in nutrient limitation in comparison to its competitors. Its capability to form mass occurrences in the Vaal River may therefore be due to a prolonged competitive advantage that allows it to create blooms in circumstances less favourable to other species.

All these results have meaning to fundamental science but what practical impact does it have on our everyday lives. This suggests that should current environmental trends persist with surface water temperatures continuing to rise and more and more nutrients continued to be loaded into freshwater systems toxic Microcystis may outgrow non-toxic Microcystis and

synthesize even more toxins. Monitoring of cyanobacteria in source waters entering DWTP has become an essential part of drinking water treatment management.

Pillar 2

Managers of DWTP rely heavily on results of water quality analyses, for their management decisions in the operating of the plants. However, these results may be delayed from 3 h to 14 days depending on a magnitude of factors such as sampling, distance, and accessibility to the laboratory, laboratory sample turnaround times, specific methods used in analyses, etc. Therefore, it would be to the benefit to managers and production chemists to be able to forecast future events of high cyanobacterial and algal cell concentrations in the source water. In our research Dr Carin van Ginkel tested several types of models, using 20 years of data from five nutrient enriched dams. Results showed that hybrid evolutionary algorithms proofed to be the best method to forecast algal blooms. This research was continued with Dr Annelie Swanepoel. In her research we used South Africa's largest bulk drinking water treatment facility to develop models for the prediction of the cyanobacterium Microcystis sp. in the source water of the Vaal Dam. Real-time prediction together with 7, 14, and 21 days in advance was accomplished. The results show that the developed rule set predicts real-time algal blooms as well as toxin concentrations quite accurately and safety steps can only be implemented when needed.

As a result, the prediction model was taken up in the water safety plan of the Zuikerbosch treatment plant and is used to predict upcoming toxins concentrations. This not only has a financial impact on the plant's treatment cost but also on their ability to produce safe drinking water timely.

Pillar 3

A key aspect of my research programme involved the investigation of the problems caused by algae in drinking water treatment plants and to aid in the application of conventional of water treatment techniques and the removal of algal cells or secondary products formed by algal cells. In all our studies total chlorophyll or biomass of algae was identified as the main risk to DWTP and commands close monitoring to ensure effective treatment.

One of the algal species that has the potential to produce large problematic blooms is *Ceratium hirundinella*. These cells are quite large, mobile and can produce tastes and odours, while mass occurrences can cause flocculation problems since these cells can change their cell surface charge and break up flocs by swimming out of the flocs. They can clog up sand filters and cause cells to break through into the final water. Results obtained from this study proved that the surface charge on the outside of *Ceratium* cells can be used to evaluate the best coagulation conditions when dosing various coagulants. This study also indicated that the pre-chlorination, without causing cell lyses, can be applied to render these highly motile cells immobile which will then subsequently assist the coagulation unit process.

The continuous increase of total chlorophyll concentrations in the nutrient rich Middle Vaal River as source water is the primary challenge for water treatment plants such as Midvaal Water Company. Midvaal Water Company has managed to treat the water successfully with a variety of combinations of water treatment processes to comply with national standards for drinking water. MidVaal gave us the opportunity to not only investigate the efficacy of pre-ozonation as a treatment process but also to investigate the effectiveness of a wastewater

recycling system to reduce costs, increase supply and at the same time not compromise final water quality.

Pillar 4

Much of our research started close to home since an ecologically healthy Mooi River system is important for maintaining the quality of potable water of Potchefstroom and surrounding areas. This system is under constant threat from anthropogenic pollution arising from both agricultural and mining activities in its catchment. Our research has shown that changes in land use can have a detrimental affect such as the increase in salinity downstream, but also an improvement such as the decrease in sulphates because of a decrease in mining activities. Similarly results from our research have shown that a change in land use impacted on both the Middle Vaal River and Koekemoerspruit, which led to changes in abiotic and environmental pollution sources that obliges stakeholders to continuously monitor water quality. In the case of the Koekemoerspruit, research emphasised the importance of a well-planned monitoring program together with the selection of representative sampling points to ensure best integrated management practices. The evaluation and review of Koekemoerspruit monitoring data have identified several shortcomings. For example monitoring of recoverable cyanide and faecal coliform bacteria have to be replaced by dissolved cyanide and *E.coli* respectively. Our studies on the impact of land use on the water quality of the Sabie, Sand and Marite Rivers that river water quality is modified by activities and processes taking place both hydrologically and in the surrounding landscape. Increased nutrients and high *E. coli* concentrations found are all indicative of deteriorating water quality due to the increased urbanization and related activities such as agriculture.

Conclusion:

The problems that South Africans experience and face regarding water quality and quantity, eutrophication, pollution, climate change, water scarcity and water demand, allows for exciting water-related scientific research and case studies but also prompts serious reflection on how we have managed to damage one of the very resources we rely on most – water. Each of us can contribute by being a citizen scientist and whether you help to teach the youth about river health or clean up your fishing spot or just use water wisely at home in the end each drop counts. I view each of our research achievements as my legacy to the next generation, my students continuing their chosen paths in the water industry is a triumph to me for the future of all of us.

As Midvaal Water Company has to consider the stressed socioeconomic status of their consumers regarding water tariffs, cost-effective monitoring and managing of the water resource is of the essence. In view of these constraints the water quality ultimately emphasized the intrinsic value of protecting water resources.

Total chlorophyll concentrations of the Koekemoerspruit did however have a significant impact on the Vaal River and also showed an increasing trend over time. The increasing trends in am-monia and total organic carbon suggested that upstream domestic wastewater effluent or agricultural runoff and not mining, currently has the largest im-pact on the Koekemoerspruit.

Recent droughts and associated conditions in South Africa have increased water users' awareness of current water demands, which are likely to increase in the future. Deteriorating source water quality together with population increases and high water quality standards have led to greater expenses in the production of drinking water