Three Strategic Water Quality Challenges that Parliamentarians Need to Know About

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Introduction

This paper gives an overview of three strategic drivers that decision-makers need to be aware of. It then presents a solution in the form of a *National Water Quality Science, Technology and Policy Program*, designed to mitigate the problems arising from these drivers. Three separate annexures are attached, each dealing with a specific technical aspect of the proposed program (Annexures "A", "B" and "C").

Three Drivers that Decision-Makers Need to Understand

The current social and economic wellbeing of South Africa has three fundamental drivers that have shaped the processes of development to date, and will continue to shape those processes as we move into the future. These three drivers are things we simply cannot change. They are so powerful that if we fail to recognize them, then all of our efforts at solution-seeking will mount to naught (at least in my professional opinion).

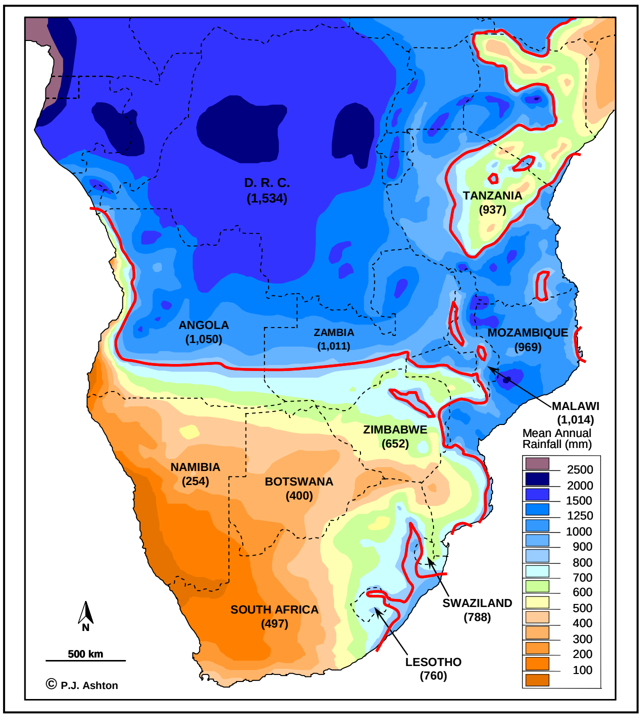
Driver No. 1: Dilution Capacity. The most important driver is the climate, and in particular our precipitation patterns. Map 1 shows the Mean Annual Precipitation (MAP) for the entire Southern African region. A few important aspects immediately become evident when one examines the data on that map. The most striking feature is the spatial distribution patterns of rainfall, with a steep gradient from north to south and from east to west. A more subtle feature is the global average of 860 mm/yr^{-1}, shown as a thick red line on Map 1. Significantly, three of the most economically developed countries in the Southern African Development Community (SADC) mainland region – South Africa, Botswana and Namibia – are all on the "wrong" side of this global average. Even more subtle is the national average, shown in parenthesis under each country name on the map. South Africa has a paltry 497 mm/ yr^{-1}, marginally better than Botswana with 400 mm/ yr^{-1} and somewhat better than Namibia with a mere 254 mm/ yr^{-1}. This has led me to conclude that water scarcity is a fundamental developmental constraint, not only to South Africa, but also to the entire SADC region (Ashton & Turton, 2005; 2008; Turton, 2008; Turton & Ashton, 2008).

An important implication of this fundamental fact is that **South Africa has lost its dilution capacity**, so all pollutants and effluent streams will increasingly need to be treated to ever higher standards before being discharged into communal waters or deposited in landfills. This gives us a very hard set of choices that need to be made:

- Either we need to change our current developmental trajectory and accept that the targets specified in the Accelerated and Shared Growth Initiative for South Africa (ASGISA, 2006) are simply unobtainable;

- Or we have a radical rethink about how to mobilize the science, engineering and technology (SET) capacity of the South African 'nation' in a concerted effort designed to support the targets specified in ASGISA.

The decision is not actually difficult to make, because if we accept the former option, then we can say, with a high degree of certainty, that social instability will grow and South Africa will slowly slide into anarchy and chaos (Johnston & Bernstein, 2007). The recent xenophobic violence is, in my professional opinion, but a foretaste of things to come, if we follow this trajectory (Johnston & Wolmarans, 2008; Sibanda, 2008). So the former is simply not an option. This leaves us with the alternative of radically rethinking how we should mobilize the national SET capacity as a matter of strategic priority. Embedded in this issue is the notion of comparative advantage, because the South African economy is already at a global disadvantage, so if we add additional costs to production, then we are faced with a double-whammy!



Map 1. Mean Annual Precipitation (MAP) in the Southern African region (courtesy of Prof. Peter Ashton).

Driver No. 2: Spatial Development Pattern. Another fundamental driver is the unique spatial pattern of development in South Africa as a country, but also within the mainland SADC region as a whole. In this regard the uniqueness arises from the fact that all of the major centres of economic development, and thus cities and urban conurbations, are located on watershed divides. Nowhere else in the world is this pattern evident to the best of my knowledge. The global norm is for large cities to be located on rivers, lakes or the seashore. But not so in our part of the world, where we have Johannesburg/Pretoria as one massive urban conurbation in South Africa, Gaborone and Francistown as smaller cities in Botswana, Windhoek as a sizeable city in Namibia and Bulawayo and Harare in Zimbabwe – all located on, or very close to, watershed divides (Ashton *et al.,* 2008; Turton *et al.,* 2006; Turton, 2008). The significance of this fact is twofold:

- It has taken major engineering and technology to mobilize the water needed to sustain these industrial and urban conurbations.

- It now means that effluent return flow out of these major industrial and urban conurbations is a major threat to future economic development, simply because the quality of the water is so degraded that it becomes unfit for human and industrial consumption (Coetzee, 1995; Coetzee *et al.,* 2002a; 2002b; 2005; 2006; Dalvie *et al.,* 2003; IWQS, 1999; Kempster *et al.,* 1996; Oberholster & Ashton, 2008; Oberholster *et al.,* 2004; 2005; 2008; Slabbert *et al.,* 2007a; 2007b; Toens *et al.,* 1999; Wade *et al.,* 2002). This is driving growing concerns from the public that will need to be addressed if social stability is to be maintained, if investor confidence is to be restored and if the legitimacy of the government is to remain intact (Bega, 2008a; 2008b; Johnston & Bernstein, 2007; Tempelhoff, 2008).

Driver No. 3: Historic Legacy. The most insidious, but potentially more volatile of these fundamental drivers, is our historic legacy. In this regard the country we call South Africa was forged out of the extreme violence of the Second Anglo-Boer War (Mills & Williams, 2006; Turton *et al.,* 2006). This was an event so traumatic that it sowed the seeds of the subsequent quest for Afrikaner Nationalism as a vehicle for recovery of a nation smashed, not on the field of battle, but by the gross injustice of the Scorched Earth Policy that targeted non-combatants, and the resultant squalor of the British Concentration Camps, in which Africans, women and children died of dysentery, cholera, starvation and despair (Hasian, 2003; Hobhouse, 1901; 1907; Van Reenen, 2000; Van Rensburg, 1980). The social pathology caused by this one historic event, which gave birth to our country as a legal entity, merged with three other sets of significant social trauma from the pre-statehood era, the combined effects of which are still being felt today:

- the plight of the amaXhosa after a century of war, which culminated in the Great Cattle Killing that broke that great nation in 1857 (Meer, 1990; Peires, 2003; Welsh, 2000);
- the ethnic cleansing in the 1820's and 1830's of many non-Zulu tribes during the *Mfecane* that laid the hinterland of the country waste, creating the vacuum into which the Trekboers moved during the Great Trek (Edgecombe, 1986; Turton *et al.,* 2004; Welsh, 2000);
- and the destruction of the amaZulu as a hegemonic nation at the Battle of Ulundi, in response to their defeat of the British at the epic Battle of Isandlwana in 1879 (Mills & Williams, 2006; Welsh, 2000).

The combined effect of these four events has created a historic legacy that is based on violence and the disrespect of human rights that still lives with us today. These historic events have given us a country without a coherent sense of nationhood (Buzan, 1991; Thompson & Lamar, 1981). **Our science is embedded in this legacy, whether we choose to acknowledge it or not.** In the context of the topic at hand, this means that all decisions taken at a strategic level need to be fully cognizant of **three vitally important consequences of our historic legacy**.

- The propensity to resort to mass violence when expectations exceed the capacity of the government to deliver (see Image 1a), with water already a political issue (Nyathi, 2008).

- The legacy that has left a country with no coherent sense of nationhood, prone to popular rhetoric that reflects crudely defined racial stereotypes, a manifestation of which is a majority of citizens who are mired in endemic poverty, with little prospect of escaping that trap, without massive government planning and support.

- The systematic erosion of investor confidence, punctuated by bouts of extreme violence such as the recent xenophobic attacks (see Image 1b), which cause great harm to the perception of the international financial community that South Africa is a viable destination for foreign direct investment.

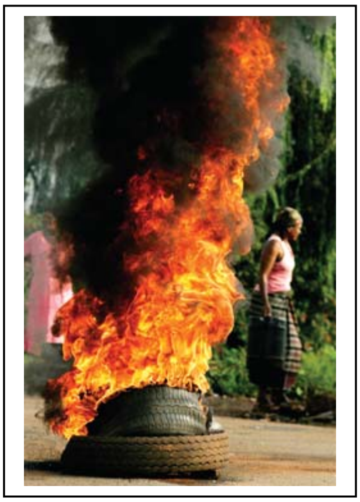


Image 1a (left) shows the extreme anger of people during riots in Phumelela and Merafong City in 2004, driven by a 'failure of service delivery', 'poor governance' and 'lack of capacity', fuelling perceptions of an uncaring and corrupt government (Johnston & Bernstein, 2007: 4 & 24). Image 1b (right) reflects the anger of people arising from failed immigration policies during the xenophobic violence that occurred in 2008 (image courtesy Ogrish.com). The propensity to resort to mass violence, when public expectations exceed the capacity to deliver, cannot be ignored in South Africa (Percival & Homer-Dixon, 1995; 1998; 2001). This violence is both unpredictable and unanticipated, which can be regarded as a manifestation of a failure to mobilize sufficient Social Ingenuity (see Barbier & Homer-Dixon, 1996; Homer-Dixon, 1995; 1996; 2000). Could this type of anger be unleashed in response to perceptions of deteriorating public health as a result of declining water quality?

So, if these three drivers are of strategic importance – our loss of dilution capacity caused by the over-allocation of national water resources, our unique pattern of spatial development, and our historic legacy – then we need to take cognizance of them if viable solutions are to be found. It is to this that we now turn our attention.

Three Strategic Water Quality Challenges

Now to deal with the title of this presentation – the identification of three strategic water quality challenges that decision-makers need to now about.

As a result of the fact that we have lost our dilution capacity, we are now faced with an increasing water quality problem. This will be addressed through the *National Water Quality Science, Technology and Policy Program* currently under development, in terms of which there will be three highly specific focal points. These are all based on three strategic challenges that decision-makers in both government and the private sector are being confronted with on a daily basis. These are the following:

Strategic Challenge No. 1: National Quest for Sustainability. South Africa is one of the few countries in the world that has legislated for sustainability in their national Constitution. We therefore need to turn these noble words into actual deeds supported by robust science. To this end the CSIR has already invested heavily in what is known as Sustainability Science. We need to now turn that theory (Burns *et al.,* 2006; Burns & Weaver, 2008) into concrete science, technology and policy. In that process our available scientific knowledge tells us that there are two major issues that are about to burst into the board rooms of large corporations and into the corridors of power in Pretoria and Cape Town. These two issues are:

- **Acid Mine Drainage**. Our entire national energy strategy is largely based on coal as a feedstock. That dependence is complex and will not be easily changed (Oelofse, 2008), so we have to focus our attention in the quest to develop sustainable solutions to AMD, both coal and gold-based (Hobbs & Cobbing, 2007; Hobbs *et al.,* 2008). This is a highly complex issue and can only be overcome by leveraging all of our SET assets in a concerted and focussed National Strategic Program with all major players in both the energy sector (coal-based AMD) and mining sector (gold-based AMD) as fully-fledged partners. To do this we must move away from the current posture of being on a quest to hold corporations legally liable for legacy issues, because that drives them into defensive positions from which cooperation is not possible. In this regard we are already learning from the German experience after unification where similar challenges arose. We need to build robust partnerships, both nationally and globally, to achieve this objective. We also need to solve technical problems that result in "new water" that is generated in a way that is both environmentally and economically sustainable. The SET component of this challenge will need to be robust, probably exceeding the combined capacity of all our existing research institutions, meaning that cooperation and partnerships are an absolute necessity. In this regard, the principle being applied is that the level of ingenuity needed to solve a problem, exceeds the level of ingenuity that created the problem in the first place. This means that by definition, no one institution will be able to solve this perplexing problem. Partnerships, and only partnerships, will be capable of achieving this strategic objective. **See attached Annexure "B" for more details.**

- **Eutrophication**. South Africa, already highly water constrained, is now also faced with levels of eutrophication that are almost unprecedented globally. Left alone this will slowly poison our waters, rendering them useless for future economic development plans and driving up production costs, further undermining the South African economy. This also has major implications for a national population that already has a high level of people with compromised immune systems (Ashton & Ramasar, 2002). The science underpinning this was lost when the transition to the mixed funding model occurred (see Figure 1). We need to rebuild that capacity as a matter of national priority. **See attached Annexure "A" for more details.**

Strategic Challenge No. 2: National Quest for Human Health. South Africa has a number of health-related challenges (Aneck-Hahn *et al.,* 2007; Bornman et al., 2005; Hunter, 2003; Mmemezi, 2008; Offringa *et al.,* 2007). One of the most notable is that associated with the scourge of HIV/AIDS that has left a substantial portion of our population with a compromised immune system (Ashton & Ramasar, 2002). Overlaid onto this is a developmental legacy that has exposed large portions of the human population to heavy metal and radionuclide contamination arising from more than a century of gold mining, much of which was largely unregulated (Adler *et al.,* 2007a; 2007b). This has many ramifications, which in my professional opinion, have not yet been unravelled in any concerted way. So, if we are to get serious about the science we do, we are going to have to show leadership in this regard. This means focussing on the following known problem areas:

- **Microcystins.** South Africa has a microcystin load in our water storage impoundments that is amongst the highest in the world. The last serious science we did on this topic was in the decade before the start of the collapse noted in Figure 1. We need to rebuild that national capacity, specifically with respect to high confidence studies of human beings that might have been exposed to chronic doses of microcystin. That work will be costly, complex and politically sensitive, but we cannot allow these factors to cause us to waiver. No high confidence studies have been done and this is bordering on the criminally negligent if we do not address this issue as a matter of national priority. We need to know if microcystins are causing human health problems (Hunter, 2003), specifically in communities that are immune-compromised, and then design intervention strategies based on this new robust science. **See attached Annexure "A" for more details.**

- **Endocrine Disrupting Chemicals**. South Africa also has a growing problem with endocrine disrupting chemicals (EDCs), driven largely by our loss of dilution. This means that EDCs are being recycled without being removed. This leads to concentration and bioaccumulation, so our focus needs to be on understanding the fate and pathways in order to design appropriate interventions, both technological and policy-related. **See attached Annexure "C" for more details.**

- **Partially Metabolized Medication**. Given our high HIV/AIDS rate, South Africa has a growing anti retro-viral (ARV) load, which passes like any other medication, through the body in partly metabolized forms. This means that we are going to be seeing higher levels of ARV in our rivers, which by implication means that these complex chemical compounds will be entering the human population over time, either through the drinking water stream or *via* produce that has been irrigated with contaminated water. This specific South African issue is nested in a bigger technical problem known as Pharmaceuticals and Personal Care Products (PPCP's), which is a growing global concern, but is sufficiently unique to warrant strategic attention on its own. We need to develop the science to understand this better, because nowhere else in the world is there a coincidence of loss of dilution and high levels of ARV use as in this country. This is clearly a national priority that has major political implications. This science might even be a world first, but it is certainly a national strategic priority in which we will have to take the lead.

- **Radionuclide and Heavy Metal Contamination**. As a result of more than a century of largely unregulated gold mining, we now have a legacy of heavy metal and radionuclide contamination in rivers flowing out of most gold mining areas. We also have a high population density living in close daily contact with dust and sediment arising from mine tailings dams (large portions of SOWETO and the East and West Rand residential complexes are located on land that in most developed countries would be considered to be contaminated). South Africa has never done a high confidence study of off-mine populations to determine what the impact has been from chronic exposure to heavy metals and radionuclides (CSIR, 2008). This will be complex and costly, but we need such a study as a matter of national urgency.

Strategic Challenge No. 3: National Quest for Climate Change Adaptation. Given that our water resources have already been fully allocated, and in many cases over-allocated, we have no more buffer capacity. This means that global climate change has very specific implications for us as a 'nation' to which we have not yet developed an adequate response (Hunter, 2003). Therefore we need to start by focussing on the following key areas of strategic importance:

- **Cyanobacteria.** While Al Gore's movie "An Inconvenient Truth" tells us to be afraid of sea level and temperature rise *in the future*, our own science is showing us that we are being threatened by toxic microcystins produced by cyanobacteria *at present* (Oberholster & Ashton, 2008) **to which we have no known solution**. The future is already here and Al Gore's movie is merely causing us to take our eye off the ball, because there is tentative evidence that cyanobacteria population dynamics are influenced, at least in part, by changing ambient temperatures in our water bodies (Hunter, 2003). We therefore need to revive the National Eutrophication Program that collapsed at the end of the 1980's (see Figure 1) in order to understand the exact linkages between climate change and cyanobacteria. Current indicators are that there is a link, but we need to drill down in greater detail to truly understand this with a higher degree of certainty. **See attached Annexure "A" for more details.**

- **Dilution Capacity.** Given that South Africa has lost its dilution capacity, we need to understand exactly what climate change will do to our national water resource that is so vital to our economic and social survival.

- **Ecosystem Thresholds.** Given that so much of our current effluent streams enter aquatic ecosystems, we need to understand their dynamics better, specifically with regard to their assimilative capacity as environmental sinks for heavy metals, radionuclides, EDCs, ARVs and the myriad of chemical pollutants we discharge daily. More specifically, we need to know if climate change will nudge any of these aquatic ecosystems across thresholds, pushing them into catastrophic collapse, such as that already in existence in the Hartebeespoort Dam system.

What I have presented here is the embryo of what is hopefully going to become the *National Water Quality Science, Technology and Policy Program*, which will reverse the trend noted by Walwyn and Scholes (2006)(see Figure 1). This Program needs of necessity to be bold and ambitious. It must have ambitious targets such as producing 50 PhD graduates after ten years, 200 MSc graduates after the same time period, and a range of patents designed to overcome the problems presented above in a way that is both financially viable and ecologically sustainable. This means working closely with every university in the country, because they will be unable to produce this number of graduates alone, and only universities have the legal mandate to do this. In this Program the CSIR would become the "space" in which human capacity is nurtured in a highly structured manner, probably with many of the existing Principal and Chief Scientists being appointed as Extraordinary Professors in these partnership universities, simply to create the supervisory capacity needed for such a massive undertaking. This can only happen if the CSIR funding model is changed, because as it now stands, those Principal and Chief Scientists are the mainstay of cash generation, rather than of the development of Technical Ingenuity in the national interest.

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Annexure "A"

Cyanobacteria in Water Resources of South Africa

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Introduction

Cyanobacteria are a group of diverse gram-negative prokaryotes and are one of the earth's most ancient life forms. Evidence of their existence on earth, derived from fossils records, encompasses a period of some 3.5 billion years (Oberholster *et al.,* 2005). Cyanobacterial blooms have become an increasing problem in South African freshwater bodies. The massive proliferation of these organisms is largely caused by over enrichment (eutrophication) of dams and rivers, which is due to progressive increase in human-derived pollution. Cyanobacteria produce some of the most potent toxins known and have no known antidotes. These biotoxins fall into three categories namely neurotoxins, hepatoxins and lipopolysaccharides. The biotoxins in the first two groups can produce severe reactions in animals and humans, while the third group appears to be less virulent (Oberholster *et al.,* 2005). However, the latter have been less intensively studied. Any release of these biotoxins into surrounding water can presents a significant hazard to humans and the ecosystem (Oberholster *et al.,* 2005). The existence of gastrointestinal disorders linked to the ingestion of cyanobacterial biotoxins, as well as the chronic risks posed by hepatoxins make these toxins a serious threat to human health when they are present in drinking water supplies.

A survey conducted in South Africa between 2004-2007 by Botha and Oberholster, used RT-PCR and PCR technology to distinguish *Microcystis* strains bearing the mcy genes, which correlate with their ability to synthesize the cyanobacterial biotoxin microcystin revealed that 99% of South Africa's major impoundments contained toxicgenic strains of *Microcystis* (Botha and Oberholster, 2007; Oberholster and Botha, 2007). Insofar as the bulk provision of raw potable water is concerned, problems posed by cyanobacterial biotoxins in South Africa are not yet of national crisis status. However, the biotoxin concentrations of cyanobacteria in major impoundments in Gauteng are so high, that a regional crisis exists if it is compared to impoundments of countries aboard (Oberholster *et al.,* 2008). Prior to 1990 South Africa occupied and acclaimed and internationally position in cyanobacterial research, but the cessation of the CSIR-driven eutrophication research program (NIWR, 1985) indicated the end of an era of world class efforts in this field. This advantage was lost due to a departmental decision by the department of Water Affairs and Forestry (DWAF) to afford a low-priority status to eutrophication and cyanobacteria in South Africa (Harding & Paxton, 2000). Furthermore, the lack of human resources capacity development in formal training of limnology, eutrophication and cyanobacterial biotoxins proved to be a significant drawback insofar as cyanobacterial research in South Africa is concerned.

Impact on Human Health

No confirmed human death has yet been attributed to these biotoxins produced by cyanobacteria in South Africa. However, acute poisoning of humans has been reported from South America, Africa and Australia. The majority (80%) of rural communities in South Africa rely on surface water as the main source of domestic water (Fatoki *et al.,* 2001). Therefore, it can be postulated that chronic exposure to low levels of cyanotoxins by people that live in rural areas, and who have compromised or suppressed immune systems due to HIV/AIDS, and possibly also suffer from other communicable and poverty-related diseases such as Tuberculosis, may experience serious social and economic consequences as a result of cyanotoxins. In 1991, it was estimated that approximately one thousand new infections of HIV/AIDS occurred each day (Doyle, 1991); this rate of new infections has continued to increase each year (Ashton & Ramasar, 2002).

Furthermore, common symptoms of cyanotoxin poisoning (diarrhoea, vomiting, stomach pains) are similar to the symptoms of gastrointestinal illness caused by bacteria, as well as other viral and protozoan infections, and are thus not immediately linked to cyanotoxin poisoning (Falconer, 1998; 2005). An important aspect that influences the toxicity of cyanobacterial blooms is the age of the victim that ingests water containing cyanobacteria. Children are more vulnerable for several reasons: they drink more water per unit of body weight; they are less likely to be able to make an informed choice of the source of their drinking water; and they are more susceptible to physiological damage that can take a considerable period of time to develop, such as environmentally induced carcinomas (Falconer, 1998; 2005). Although young children bear a considerable burden in terms of diarrhoea, school-age children also suffer the effects, resulting in school absenteeism. The adverse effects on education are likely to go far beyond the number of days lost per year, as absenteeism increase failure rates, repetition of school years, and drop-out rates. For children under 5 years of age, diarrhoea is the third most important cause of death after HIV/AIDS and low birth weight, and represents 10 % of all deaths in that age group in South Africa (Bradshaw et al., 2003). The only available estimate of the cost for the treatment of diarrhoea in South Africa is that R3.5 billion is spent every year as a direct result of diarrhoea (Pegram *et al.,* 1998). However, there is insufficient evidence to confirm that chronic exposure to low levels of cyanobacterial toxins has played a role in these cases due to a lack of analytical ability. The science has simply not been done, so we remain in ignorance of this important issue affecting millions of South Africans on a daily basis. In addition, a study to assess the chronic human health hazards caused by the biotoxins of cyanobacteria toxin ingested over long periods, such as might occur through drinking water from untreated sources, was undertaken on human lymphocytes in vitro. It was found that the cyanobacterial toxins produced more chromosome damage than did benzene and sodium arsenite (Pitois *et al.,* 2000).

A study conducted by Humpage and co-workers (Humpage *et al.,* 2000) indicated that microcystins from a cyanobacterial extract provided in drinking water to rats increased the area of aberrant crypt foci in the colon, suggesting that microcystins promote preneoplastic colonic lesions. More importantly, microcystins are potent tumour promoters (Nishiwaki-Matushima *et al.,* 1991) and there is an indication that they also act as tumour initiators (Ito *et al.,* 1997). Epidemiological studies have suggested that microcystins are an important risk factor for the high incidence of primary liver cancer in certain areas of China, where people have consumed pond-ditch and river water contaminated with low levels (within the range of 0.09-0.46 μg/litre) of microcystins (Ueno *et al.,* 1996). Furthermore, bathing and showering in water containing cyanobacterial cells can results in allergic reactions resembling hay fever, asthma and skin, eye and ear irritation (Bell & Codd, 1994). A new emerging problem include the production of β-N-methylamino-L-alanine (BMAA), a neurotoxic amino acid which is a possible cause of parkinsonism-dementia in humans and which is produced by all known groups of cyanobacteria (Cox *et al.,* 2005).

Crop Irrigation

Between a third and half of South Africa's population is dependent on subsistence, small-scale farming (ASSAF, 2006) (Table 1).

Subsistence farmers	**Minimum**	**Maximum**
Numbers	1500 000	3000 000
Number dependent	4500 000	21000 000
Percentage (%)	9%	44%
Farm size	≤ 1 ha	≤ 5 ha
Emerging farmers with small scale commercial operations	**Minimum**	**Maximum**
Number	250 000	500 000
Number dependent	750 000	3500 000
Percentage (%)	2 %	7%

Table 1. Percentage small scale farmers in South Africa. Source (ASSAf, 2006).

The majority of small-scale farmers and emerging farmers used surface waters from farm dams or rivers to water their crops. Because these water supplies may contain cyanobacterial blooms and biotoxins, the exposure of edible crop plants to cyanobacterial toxins may cause these toxins to accumulate in plant tissues (Codd *et al.,* 1999). The introduction of these toxins into the human food chain is therefore a strong possibility, which may pose great concern for human health if these crops were ingested. Unfortunately, nothing is known about this exposure route in South Africa, because the science has never been done. Furthermore, spray irrigation may permit cyanobacterial biotoxins to affect commercial plant industries as this method of irrigation has previously been shown to be an exposure route for cyanobacterial biotoxins (Abe *et al.,* 1996). Whether spray irrigation promotes cyanobacterial biotoxin release on crops due to cell breakdown *via* sheer stress, is not yet known. Strong evidence does exist that cyanobacterial biotoxins inhibited the germination of pollen which could have an adverse effect on crop yield of emerging black farmers (Metcalf *et al.,* 2004).

Policy Implications

If South Africa is to deliver on the Millennium Development Goals (MDGs) and on the Constitutional imperatives of an environment safe from harm, then it is vital that the scientific capacity be rebuilt at a national level. South Africa once had a robust national program, doing world class research, but that has all been lost. Decision-makers therefore need to be aware of these problems because they affect a large portion of South African society.

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Annexure "B"

Parliamentary Briefing Paper on Acid Mine Drainage

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Introduction

Mine water pollution has been identified by the Department of Environmental Affairs and Tourism (DEAT, 2008) as an emerging issue "… *that may affect the future state of the environment*" and, as such, qualifies for inclusion in the next state of the environment (SoE) reporting cycle. The reality, however, is that contaminated mine water, also known as acid mine drainage (AMD), has already manifested itself as a clear and present danger to the environment. The much publicised (and televised) situation in the Wonderfontein Spruit catchment arising from gold mining activities (see for e.g. Coetzee & Venter, 2005; Coetzee *et al.,* 2006; Hobbs & Cobbing, 2007; Naicker *et al.,* 2003; Oelofse *et al.,* 2007), and in the Olifants River catchment due to coal mining activities (e.g. Bell *et al.,* 2001; Hobbs *et al.,* 2008; Hodgson & Krantz, 1998), testifies to this.

In a certain sense, South Africa finds itself in a similar position to that which faced Germany after reunification in 1990. The lignite and uranium mining activities practised in the Federal States of Saxony and Thuringia in the former East Germany (German Democratic Republic), as well as the chemical industries in the Bitterfeld area, left behind a devastated landscape and environment. The responsibility for the rehabilitation of these legacies fell to the Federal Republic and the respective Federal States.

Why Is Acid Mine Drainage A Concern?

An appreciation of why acid mine drainage is a concern is provided by the following facts and figures. Acid mine water is a pernicious contaminant that not only sterilises its receiving environment, but also carries trace elements such as heavy metals and radionuclides in concentrations that are potentially hazardous to all forms of life. Whilst manageable in small quantities, the potential volume resulting from more than 100 years of gold and coal mining is alarming. For example, the volume of acid mine water currently coming to surface in the West Rand goldfield near Krugersdorp is sufficient to fill at least 10 Olympic-size swimming pools (2,500 m^3 each) every day (Figure 1). The daily salt load in this water is equivalent to almost 140 tons, the mass equivalent of 70 medium size sedan cars. These values can quite readily be multiplied tenfold (Figure 2) to obtain an order of magnitude (and probably still conservative!) number for the entire Witwatersrand Basin comprising five goldfields. In addition to the West Rand goldfield already mentioned, these are the East Rand, the Central Rand, the Far West Rand and the KOSH goldfields. By comparison, the Olifants River catchment witnesses roughly double the West Rand Basin values from defunct coal mines in the Witbank coalfield. The situation in the other coalfields (e.g.

Highveld and Ermelo) located in the catchment of the Vaal Dam, is still largely unknown.

Clearly, the potential volume of poor quality mine water threatens to significantly reduce the utility of the already stressed freshwater resources of especially the economic engine-room of the country. Further, the impact of mine water quality on humans is largely unknown and has not yet been studied in South Africa (Adler *et al.*, 2007). A proposal is currently before the Water Research Commission to address this deficiency (CSIR, 2008). To consider once more the similarities with Germany following *die Wend* (The Turning Point) in 1990, and South Africa's own *democracy* in 1994, the negative externalities associated with historical mining activities and the imposition of these costs on society (Adler *et al.,* 2007), demonstrate an alarming similarity.

What Needs To Be Done?

Apart from recognising the threat posed by AMD as a matter of utmost urgency, the relevant authorities at all levels of Government need to leverage and mobilise the scientific and technological expertise offered by the various statutory research councils (e.g. CSIR, CGS and ARC), and the strategic support provided by the Water Research Commission (WRC). These organisations need to be regarded as allies and partners in addressing the threats posed by AMD. The 'master / servant' relationship which has for long characterised such associations does not foster an effective, cooperative and solution-driven approach to dealing with the threat.

It is also required that a clearly defined programme, supported by the necessary level of funding, be implemented. It is important that such a programme recognises the multi-disciplinary nature of the research that is required, and is predicated on collaborative teamwork across a wide range of specialist fields.

Finally, the experience of German regulatory authorities and researchers to successfully address similar challenges provides a well-spring of knowledge that we ignore at our peril.

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Annexure "C"

Parliamentary Briefing Paper on Endocrine Disrupting Chemicals

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Introduction

Along with Rachel Carlson's book the "*Silent Spring*" in 1962, came the realisation of the potential danger of certain chemicals to humans and the environment. She questioned people's faith in technological advancement by exposing the hazards of the pesticide DDT (NRDC, 1997). During the past two decades, there has been global recognition of the potential effects of a number of chemicals that are used during our daily activities. In South Africa some 10 years ago, the Water Research Commission (WRC) realised that most of the health-related water research done to date was mostly based on microbiological water quality. This was not reflecting global trends and subsequently included chemicals known as Endocrine Disrupting Chemicals (EDCs) into their research strategy (Water Sewage and Effluent, 2008). This resulted in the South African EDC Research Programme under the leadership of the WRC in 1999. In 2002 the WRC hosted the first Global Water Research Coalition (GWRC) workshop on EDCs in South Africa. Much effort has since been put in place to determine the presence and effects of these substances in our water system. Today, over 80 000 chemicals are registered for commercial use and it is still unclear how many of these are potential EDCs (IPCS, 2002). The Department of Water Affairs and Forestry (DWAF) therefore compiled a priority list of chemicals suspected of eliciting EDC capabilities.

What are Endocrine Disrupting Chemicals (EDCs) and why are they a Problem?

Endocrine Disruptors or Endocrine Disrupting Chemicals (EDCs) can be natural or man-made and have the potential to alter the normal functioning of the endocrine system. The endocrine system is responsible for guiding the development, growth, reproduction and behaviour of both humans and animals (IPCS, 2002).

An understanding of the human bodily functions and the role of the endocrine system is necessary to fully appreciate the effect EDCs have on a living organism. The endocrine system regulates processes as diverse as blood pressure, smooth muscle contraction, fluid balance and bone metabolism (IPCS, 2002). For many of the systems, the setup is "programmed" during foetal development. An abnormal environment during this critical stage can therefore result in permanent mis-programming (IPCS, 2002). To complicate our ability to measure endocrine disrupting effects, it has been found that these substances have transgenerational capabilities (IPCS, 2002, American Chemical Society, 1998). This implies that not only can these adverse effects result from exposure of either parent prior to conception, but it can also result from exposure of the developing embryo in utero, or from exposure of the progeny after birth (Daston *et al.*, 2003).

In simple terms this implies that our exposure to these chemicals may only manifest and become apparent in our grandchildren. The effects can also be visible in all three generations, or the effects may only manifest years later. The question is – how do we deal with this and how do we manage exposure from now on?

Chemicals suspected of being endocrine disruptors are pesticides, fertilisers, pharmaceuticals (e.g., birth control), personal care products (e.g., shampoo, lotions, perfumes, cosmetics, sunblock), and industrial substances (e.g., plasticisers, fabric softeners and cooling agents). These chemicals find their way in to our environment and we are in contact with them through all the major exposure routes such as the air we breathe, the water we ingest, the food we eat and through our skin. Effects of these substances on animals have been widely published (e.g., subtle changes in physiology and sexual behaviour of wildlife species to permanently altered sexual differentiation; marked population decline in Baltic seals; eggshell thinning and altered gonadal development in birds of prey) (IPCS, 2002).

There is still much debate surrounding the significance of evidence and linkage of these chemicals affecting human health. One cannot control human exposure, which makes it difficult to prove. To complicate things, high confidence epidemiological studies and hard scientific evidence are mostly lacking, specifically in developing countries. It is assumed that if animals are affected, EDCs must be affecting humans too. International studies in the US and in Japan have reported on a decline in sperm counts in males over the last 50 years. There has also been a marked decline in the number of male births. Increases in certain cancers in both males and females have also been linked to potential effects of EDCs (IPCS, 2002).

In South Africa the evidence of EDCs in our water system has been wide spread. Levels of EDCs in drinking water sources equal to those reported to cause feminisation of certain fish species have been reported by Routledge *et al.,* (1998). Drinking water from both groundwater and surface water sources, and sediment samples have been tested positive for a variety of these substances (Bornman *et al.,* 2005; Awofolu & Fatoki, 2003; Slabbert *et al.,* 2005; Dalvie *et al.,* 2003). Significant levels of selected endocrine disrupting chemicals were found in fat tissue of certain fish species (Barnhoorn *et al.,* 2004). Aneck-Hahn *et al.,* (2002) and Hurter *et al.,* (2002) reported on oestrogenic activity found in water. The most controversial and devastating results found to date are the impaired sperm quality and uro-genital birth defects found in DDT sprayed areas of South Africa (Aneck-Hahn *et al.,* 2007; Bornman *et al.,* 2005).

It is therefore clear that these substances are present in our environment and we are exposed and affected by them on a daily basis. The extent of our exposure and the potential for risk of adverse effects in humans are not clearly visible yet, but are we prepared to risk not knowing?

The Way Forward

EDCs have recently received more attention with the publication of a world first pilot study done at a nature reserve in South Africa. This is considered to be the most comprehensive study on EDCs to date (Bornman *et al.,* 2007). The CSIR plays a vital role in assessing the potential risk of these substances in water to human health and are currently working on a framework to develop guidelines for South Africa. Research projects about the occurrence and fate of EDC during wastewater treatment, drinking water treatment and in soil are in progress, while several projects for analytical method developments are also ongoing.

South Africa finds itself in a unique position as we are currently on the forefront of research on this topic. We should therefore strengthen this programme to ensure we stay abreast of global developments. South Africa is one of only a few countries still using DDT to manage malaria, but we are now seeing health impacts from this, so soon there will be a national debate on the trade-off's between reduced malaria versus increased urogenital defects in children and other reproductive disorders. We need to focus on efforts to establish our uniqueness, building on our strengths. Above all else, we need to be proud of this achievement and develop this programme further.

Despite much progress made through the South African EDC Research Programme, scientists feel that they have hardly discovered the tip of the iceberg, and much more work needs to be undertaken. Most of the activities to date have been aimed at refining scientific measures to improve our national research capacity. Most of the effort has also been based on the reproductive function of the endocrine system, since this was shown to be more vulnerable when exposed to these chemicals.
Epidemiological studies need to be done to establish dose-response relationships. More research should be done to also establish the effects on systems other than the reproductive function of the human body. Metabolism (e.g., pharmacokinetics) of these chemicals within the human body need to be better understood. Priority should be given to the transgenerational capability of these substances, as well as the synergistic and antagonistic effects of exposure to a cocktail of these chemicals in our environment (e.g., air, food, water), specifically as a legacy of Apartheid.

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