WATER RESEARCH COMMISSION

WORKING PAPER

Citizen Science for water resources management: The time is now! (A Working Paper)

by

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Summary

Citizen science is exploding in popularity all around the world. And for good reason! It's fun, it illuminates mysteries, and it makes it possible for everyone to experience real research. The World Economic Forum (January, 2021) makes it abundantly clear that there can be no sustainable economic growth on a sick earth. All forms of developments depend on healthy natural ecosystems and the services they provide. It is unfortunate that globally, we continue to lose habitats, species, experience worsening pollution. These conditions are made worse by limited practical interventions on climate change mainly by rich nations who benefitted from burning fossil fuels (Kate Raworth, 2018 and Webinar-Feb 2021, can doughnut economics help us recover from the COVID:19).

The most apparent concern globally is the dwindling water resource quality and quantity data. This is clearly marked in the SDG:2030 report published in 2021. Indeed, this desperate situation is mentioned in the National State of Water Resources of South Africa published by the Department of Water and Sanitation in 2021. On the other hand, nationally and internationally, there is an increase in ecosystem degradation, hence the additional call by the UN to secure and implement restoration of these ecosystems within a decade from today, i.e.by 2030. This emphasis is re-enforcing restoration calls already listed under several SDG: 2030 Goals. In the light of data gaps the UN has made a call to member states to seriously consider supporting citizen science data and information generation and, where possible, align this with mandatory monitoring for quality control and assurance. It is also well acknowledged that trained citizen scientists (CS) collect far more data than mandated organisations in space and time. It is therefore a service that is hugely underutilised.

Various attempts have been made by countries, including South Africa, to secure the validity and acceptance of the CS data by researchers and policy. To gain policy support, the WRC and United Nations Children Fund (UNICEF) committed to jointly fund a project in which one objective is to produce a state of water resources using CS data. Other initiatives include streamlining CS data and information into policy decision-making; develop quality control mechanisms, recommend sustainable CS network, engage more youth as future leaders, explore entrepreneurship opportunities, and use of technology and social media in water resources monitoring.

UNEP (2021) is equally committed to supporting CS development and its strengthening across the global communities, especially member states. This working paper is exploring the real CS as opposed to survey, action research and other short-term related efforts. This is critical to reach consensus on. Secondly, we unpack the barriers and enablers to a flourishing CS and lastly the uptake by policy.

Introduction

Citizen science is not a new concept. In fact, the first formal use of the term "citizen scientist" can be found in the magazine *New Scientist*, October 1979. Prior to this time, it was an informal exercise driven by passion, particularly photographers. Citizen science (CS) is sometimes described as public participation in scientific research, participatory monitoring, or participatory action research whose outcomes are often advancements in scientific research by improving the scientific community's capacity, as well as increasing the public's understanding of science. In abbreviated form, it's also referred to as **community**

science, **crowd science**, **crowd-sourced science**, **civic science**, or **volunteer monitoring.** It is a scientific research conducted, in whole or in part, by amateur scientists or ordinary citizens often in collaboration with scientific research led by experts, (Wikipedia). It is very important to differentiate between CS and once off survey or even the action research where scientists utilize individual community members (or groups) to collect data for the benefit of the research study and duration. This has short time equal to that of the study, beyond that there is no sustainability built in, tested indicators, common vision. Globally and indeed in the country there is a rapid decline in data collection by the mandated organizations with serious impacts on informed policy development, natural resources management as well as predictions/modelling. According to the recent United Nations Environment Programme (UNEP, 2021) on Ambient Water Quality very few countries collect/or submit data.

A clear message is evident from both the 2017 and 2020 data drives that the **capacity to monitor is much less, particularly in low-income countries.** In many of these countries, water-quality data are not routinely collected, meaning that over **3 billion people** could be at risk because the health status of their freshwater ecosystems is unknown. Without monitoring, there is an information gap on the current health of aquatic ecosystems and no baseline against which to measure future change. This means that health and livelihoods, which are dependent on the services provided by these ecosystems, are at significant risk if the ecosystems are not able to continue to provide services such as clean water to drink and fish for livelihood. The situation with groundwater is dire. Of the 89 countries with data available, only 50 have information about groundwater. This is particularly problematic when considering that groundwater often represents the largest share of freshwater in a country. An understanding of the hydrogeological environment, the pressures on these resources, and how to monitor them effectively is lacking in many countries.

The World Economic Forum in its listed risks (2021) continues to report water crisis, biodiversity, in-action on climate change as some of the top priorities facing the humankind and it is getting worse. Protection is easier than restoration, so efforts to protect these water bodies must begin as a matter of urgency (UNEP, 2021). In South Africa, all water resource types are threatened well beyond 65% due to various sources of pollution (NBA, 2019), see Figure 1 below. To add to the dire situation is the spread of highly thirsty alien and invasive plants and impacts of climate change, as reflected in the frequency of droughts. All these threaten water security, which is key in job creation, especially in developing countries. Citizen scientists' role is midway between the general public and scientific research community, which puts citizens in a position to close the chasm between these two, as well as policy and politicians. "From the Second International Handbook of Science Education, a chapter entitled: "Citizen Science, Ecojustice, and Science Education: Rethinking an Education from Nowhere" by Mueller and Tippins (2011), notes that: "There is an emerging emphasis in science education on engaging youth in citizen science." The authors also ask: "whether citizen science goes further with respect to citizen development." The article ends by stating that the "chapter takes account of the ways educators will collaborate with members of the community to effectively guide decisions, which offers promise for sharing a responsibility for democratizing science with others". Managing rivers, wetlands, estuaries and ground water is obviously a task way beyond officials in any state, hence the unavoidable call for citizens' involvement.

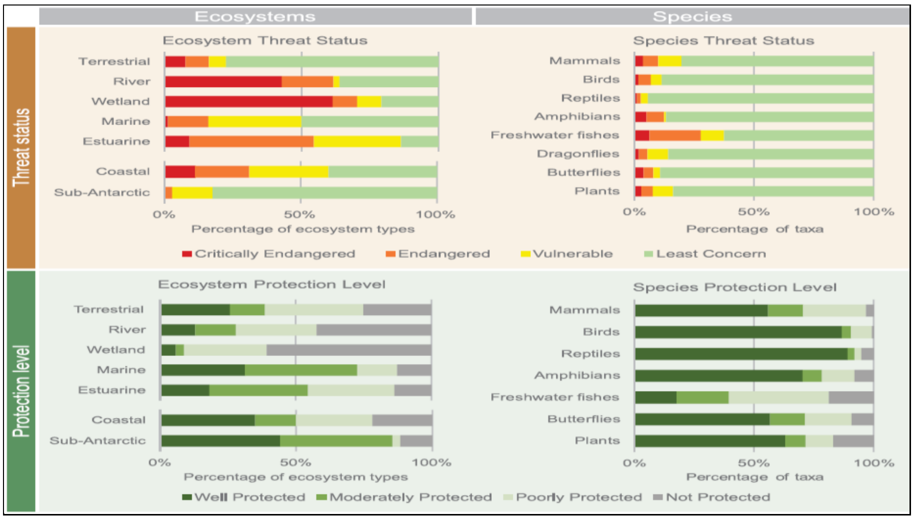

Figure 1. The worrying state of South Africa's water resources (NBA, 2019). Pictured below is waste trapping made up of connected simply drums put across the river to stop plastic from drifting downstream (Source: Hennops Rivival, 2021)

Citizen science design

In 1994 (prior to the publication of the National Water Act, No 36 of 1998-NWA), the Department of Water and Sanitation (DWS) designed a successful programme, namely the River Health Programme (RHP). As it was designed before the NWA it was not aligned with the democratic dispensation and changes in legislation, for example, in water allocation. The NWA required that no one owns natural raw water, but the state becomes the custodian and ensure fair accessibility and equity", carried in a slogan -Some for all Forever". The NWA also distributed water resource management across all levels of legislation and society through establishment of Water Management Areas and Forums at provincial and local levels, respectively (Figure.2).

Figure 2. A shift from 1956 water Act to 1998 National Water Act recognised the citizens as key stakeholders in IWRM.

This democratization of water resource management gave a voice to the previously voiceless members of the society and individuals.

Following this development, Dickens, et al (2002) came up with a simplified combination of RHP indicators (macroinvertebrate sensitivity scores) which were easy to identify by any member of the community because they did not demand technical skills. They were tested against the RHP monitoring results and found to send exactly the same message at a very low cost. In 2008, triggered by a parliamentary question from the opposition party, (Democratic Alliance, Mr Douglas Gibson) regarding the entire health of rivers of South Africa, the DWS designed volunteer programme targeting pensioners, school pupils, industries, catchment forums, water user associations, municipalities, citizens, etc. The spin-offs being water saving, skills development for youth, empowerment of the general public on Integrated Water Resources Management (IWRM), improvement of water quality and of the state of the rivers. The concept and thinking behind the project was sound and looked very promising. Then Department of Water Affairs (DWA, 2009) published a document entitled "*Adopt-a-River Programme Phase 2 (AaRP): Development of an Implementation Plan/ Institutional Aspects and Governance Structures*", to be launched by the then Deputy Minister, Rejoice Mabudafhasi in 2010, see Figure 3 below.

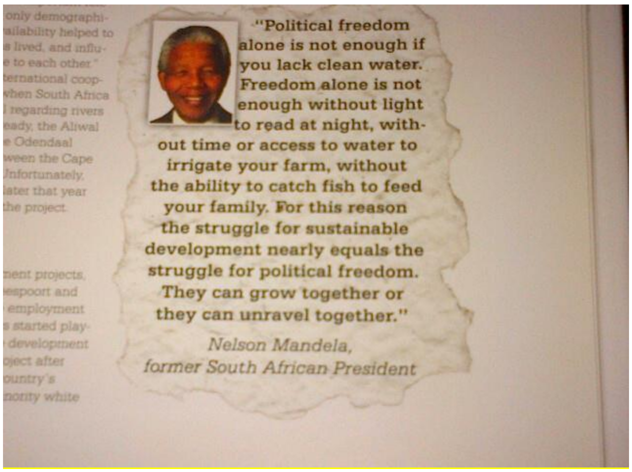

Figure 3. The first democratic president of the Republic of South Africa, Nelson Mandela's quote on value of water and the then Deputy Minister of Water and Environmental Affairs, Ms Rejoice Mabudafhasi taking a miniSASS sample launching adopt a river in 2010.

In 2016, Graham, et al (**WRC Report No. KV 354/16**) produced a revised AaRP taking into consideration the global support of citizen science monitoring efforts. This led to the development of miniSASS (**WRC Report No. TT 763/18**) and other citizen science monitoring tools, including flows, clarity tube, etc. These tools were specifically designed for non-technical persons for water quality monitoring based on accredited technical protocols used by the DWS and other experts in water development and licensing processes. More about tools later.

In her presentation, Helen, et al (SER 2021 conference) reported that with the aid of trained citizen scientists using low tech based on Google Earth Pro (GE) imagery, identified far more sites needing restoration in a short space of time compared to mapping by researchers only. Taking an example of ecosystem restoration, which is so urgently required in South Africa and beyond, its successful achievement depends heavily on the empowerment, understanding and participation of citizens at local scale. Indeed, the diversity of stakeholders and their interests can easily lead to conflicts that pose a threat on restoration success. Social-Learning is central to approaching and creating relationships with citizen scientists and must be based on mutual TRUST, co-benefits, sense of belonging, cultural respect, sharing similar vision and outputs/outcomes. The theory of change provides the framework for managing target times, expectations as per realistic objectives taking into consideration the financial limitations, recovery speed and returns. A sustainable intervention, such as in water security requires that the design of the programme involves citizen scientists from conceptualization, not a top-down approach so that the outputs are as much of their desire as they are of the intervention envisioned by scientific experts. The local community must feel their role, contribution, relevance and ultimately ownership of the intervention. Ideally, citizen science should be founded on a voluntary basis for the benefit of the society in the first place with minimal budget required, such as in acquiring instruments. The protocols for data collection must be as simply as possible without compromising the quality and reality of the observations. Figure 4 summarizes the CS design steps to deeply consider.

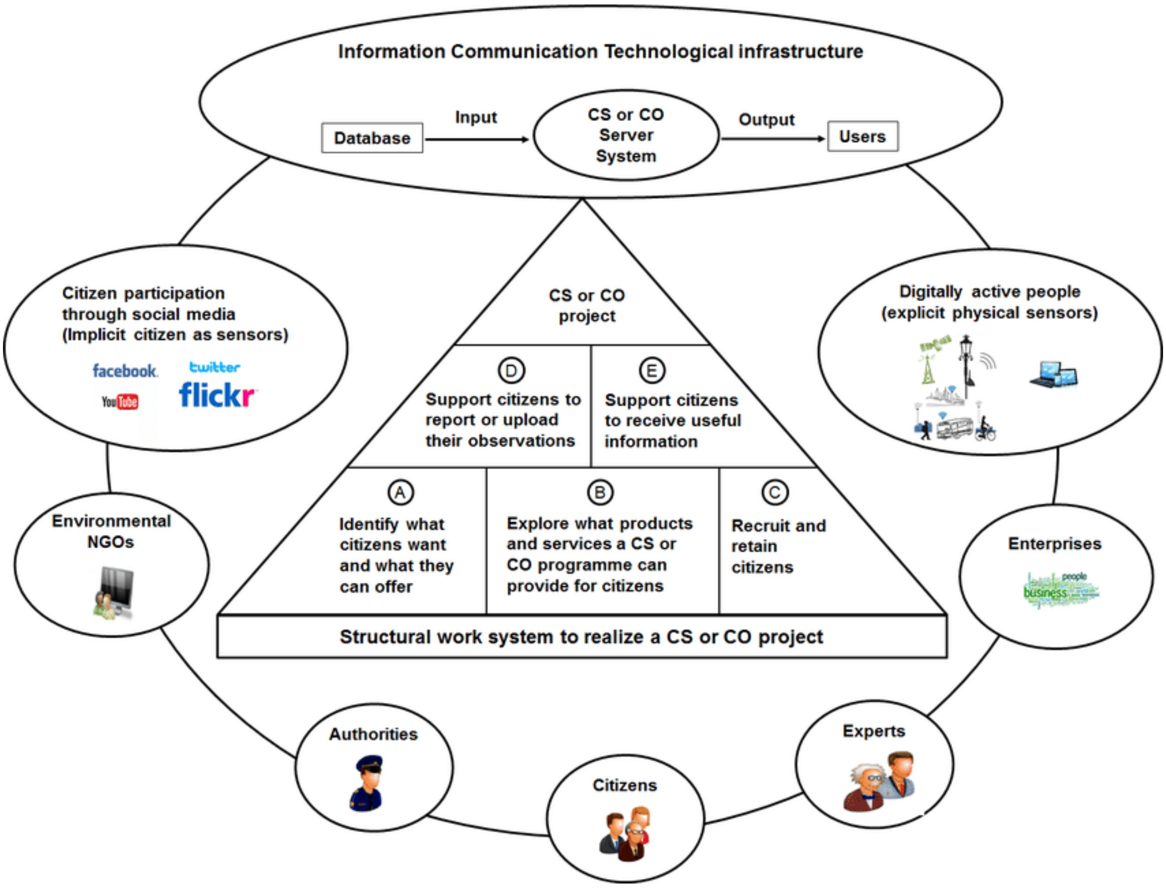

Figure 4. The model design of the citizen science programme must be truly scientific, simply, adaptable and appealing. Source: Liu, H-Y, Grossberndt, S and Kobernus, M. 2017. CS = citizen science/scientist, CO = citizen observatories.

It is easy to lose citizen scientists by asking them to conduct complicated calculations, scientific analysis, and one has to be reminded that they are volunteers. Their efforts are not necessarily to be paid, except where incentives are unavoidable. Citizen science is not about simply data collection, but rather analysis and reporting. Most importantly, it can create change on the ground as per indicators and long-term monitoring. This can be in the form of enhanced biodiversity, return of species, greener landscape, better quality of water and quantity, healthier and breathable air, etc. Therefore, data alone is useless, it must be interpreted to impact and influence, e.g. policy change/performance, learning/educate, incorporated into textbooks, change people's behavior towards greener ways, etc.

Citizen science challenges

While citizen science has been around for a couple of decades as an appreciated and capable contributor to knowledge generation, it still has not received credibility across the board, be it technical scientists or natural resource managers. Its pathway to policy implementation is an ongoing battle (see Figure 5). Sustaining the role of citizen scientists depends on several factors, some of which include the reliability, regular feedback, simplicity and up to date protocols (taking advantage of technology, Apps, etc), remaining relevant, training and re-training of the participants especially the new recruits. The inclusion of youth and technology in monitoring or data collection, machine learning and many others.

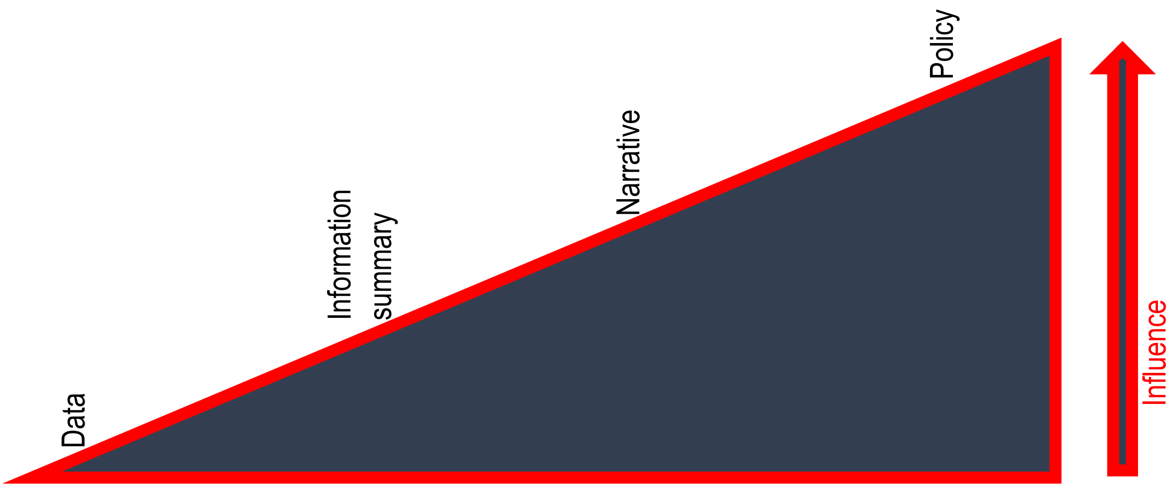

Figure 5. The long navigation process of the CS data to acceptability and uptake by authorities. From database, through summary and narrative, to influence (e.g. in policy space). (Prof: Underhill, 2021)

It is critical that several practitioners across the world continue to explore CS, standardised sampling methods and work on data credibility. One typical example in spreading CS across different regions is the study which will commence in January 2022, which will be undertaken by two MSc students, one based in Ethiopia and the other in KwaZulu-Natal, supervised by Prof Seifu Kebede Gur-messa of the Centre for Water Resources Research, UKZN. There are several trainings across the country using WRC funded monitoring toolbox and others. However, these efforts are sporadic and uncoordinated, hence the upcoming joint project call by UNICEF/WRC is focused on coordination, planned to start in 2022. The same project will aim at producing the first ever state of water quality in South Africa: a CS perspective. This is meant to provide evidence (particular to policy) on the value of CS data. The environmental departments, DFFE/DWS have CS in their strategies, but still reluctant on uptake and use of CS in decision making due to lack of tangible products at a national scale, as well as uncertainty on the quality assurance. The latter is a concern to most professional scientists as well. This has also led to SDG reporting not incorporating CS. However, this is fast changing with the recent call by SDG:2030 international reporting team to update and accelerate ambient water quality indicators (UNEP, 2021), with particular reference to MiniSASS. The case study below illustrates efforts made by DUCT (NGO), and Enviro-champs from uMngeni catchment, kwaZulu Natal. Such efforts need to be urgently duplicated across the country in order to generate data at scale important in producing convincing state of water resources and indeed call for rehabilitation and better water resources management.

Case study: uMngeni- Amanzi Abantu

In the first half of 2021, as a part of the Presidential Employment Stimulus Programme (via the Department of Science and Innovation) the Duzi-uMngeni Conservation Trust (DUCT) piloted a multi-partner **blended finance community-public-private-partnership model** in the uMngeni catchment, with 300 young people doing work for the environmental common good. From the river source down to the sea, young people worked with various partner organisations to clean, clear, educate, and bring change in their local community streams. Alongside this good work, they were trained to use **citizen science tools** to gather data on the state of their local rivers. **The Amanzi Ethu Nobuntu Programme was born**.

The programme was recognised for its logical innovation, and its potential for scale up as a solution to our environmental pollution challenges, while supporting unemployed youth. As an example of success and confidence, DSI further awarded the team with a second phase for the period of October 2021 to March 2022 (possibly extending to May), with a greatly expanded budget (R25 million), and **a goal of providing 500 income opportunities**. This is just the start. We are in the process of working with the Department of Science and Innovation, and the Office of the Presidency to make this a medium-term programme at a national scale. Universities, the Water Research Commission, SANBI, Msunduzi Municipality, and Umgeni Water are just some of the organisations providing support to grow this into a game changer for South Africa. The goal is to create: **A sustainable massive national transformative innovation 'work for the common good' programme to assist with monitoring water quality and related ecological degradation concerns within a systems-based, citizen science and civic action approach (**Ms Faye Brownell of DUCT, personal communication**).**

The other effort on learning from society regarding their indigenous or local knowledge is driven under the GEF 6 funded component, called Ecological Infrastructure for Water Security (EI4WS). Heila Lotz-Sisitka, et al (K5/2854) goes into the details of democratizing science and integrating CS in institutional governance framework. Relationship between science-society and policy partnership is detailed through several models of civic and CS. The most recent work is on exploring groundwater quality monitoring by CS, Jacqueline Goldin et al. (K5/00085), Hout Catchment, Limpopo). This is still at early stages as a credible set of protocols development is underway. This is a major contribution, especially where communities rely heavily on groundwater for livelihood. Finally, CS data is an envisaged contributor to the WRC water observatory project initiated in 2020 as well as developing text-mining tools to collate CS generated data from various online sources.

Discussion

Several papers reviewed all agree on the need and role of citizen scientists as well as recognition of this community of practice as part of science, but that is not the same for policy. Worldwide interest and participation in citizen science continues to grow. Data availability remained the greatest challenge for countries during the 2020 drafting of the SDG 2030 report (UNEP, 2021)). This was most evident in low-GDP countries, which reported on less water bodies and used less data to classify their water bodies compared with richer countries. Chapter 3 of the UNEP report, (2021) reports that twenty countries with the lowest GDP of those that reported, reported on only a fraction of the total number of water bodies reported globally. Lack of data inputs affect the countries reporting obligations to the UN, hence the low confidence in the SDG 2030 regular reporting.

The latest national state of water resources report in South Africa confirms the crippling lack of data (Department of Water and Sanitation, 2021). The release of nutrients from agriculture and untreated wastewater poses the most widespread threat to environmental water quality globally. An in-depth analysis of submissions from countries that supplied parameter-level data showed that nitrogen and phosphorus failed to meet their targets more often than the other water quality parameters of Level 1 reporting. This means that for these countries, and likely for most countries, **reducing nutrient release and transport will have the greatest positive impact on water quality** (UNEP, 2021). Capacity development is needed to help fill gaps in key areas within the organizations tasked with reporting. Sometimes it is not only human resource capacity, but analytical equipment, analysis and reporting skills or errors. The other factor is the political will and investment in water resource monitoring networks, including that of CS despite having legislative support in strategies and numerous environmental protection acts in South Africa.

MiniSASS has adhered to the complete value chain, from data collection, analysis, database, and reporting. Besides MiniSASS, other prominent tools tested and ready for CS use include Turbidity tube, velocity (flow) meter and *E.coli*. These tools were tested during development in many countries outside South Africa, including Canada, Mexico, South Korea, Tanzania, Zambia, eSwatini and Lesotho (WRC **Project no. K5/2350**). Though there is no manual on quality assurance/control, the experts archiving data are well trained and are able to spot outliers or totally improper data entries, loaded on the databased. The manual is the subject of the upcoming research call led by the WRC. Monitoring and assessment of groundwaters is the latest addition to CS in South Africa, Jacqueline Goldin et al. (K5/00085), it is still on verification of monitoring indicators beyond the Hout Catchment study area. Such test is critical across the country and appropriate training in rolling out the protocols. All catchments are different; robustness and repeatability of the tool are critical before it is added to the toolbox. Included in testing is the quality assurance and control, loading on database and reporting.

The first South African state of water quality resources assessment is due in 2023 through a joint project led by UNICEF/WRC. To sustain training of CS across the country despite the impacts of the COVID-19 pandemic, an online project will start in April 2022, funded by the WRC. WRC is also looking at adding air quality indicators to be monitored by the CS, particularly where air quality presents greatest challenge, such as where fossil fuels are burnt for coal production, e.g. in Mpumalanga.

Once data collection and management practices have been strengthened, for greatest impact, these generated data need to be embedded in management and policy actions, and combined with improvements in outreach and communication aimed at all stakeholders to ensure that water quality becomes everyone's business. The Strategic Plan for the ninth phase of the Intergovernmental Hydrological Programme (IHP-IX) covering 2022-2029 also believes that the citizen science has become a tool for hydrological research, enabling the efforts of scientists and citizens to collect data for research to be interpreted by scientists for decision-making. Advances in user-friendly technology, including those in the virtualarena, also facilitate communication, training and online data visualization and data collection. From a science perspective, citizen science widens spatial and temporal data collection possibilities, particularly at the local scale.

Many citizen science initiatives and research projects already exist and may add to the big data available already through open science and open access initiatives. Concerns about the accuracy and quality of data generated through citizen science hamper full acceptance of such data. There is a need to further elaborate on how and where quality control and quality assurance problems in citizen science data can arise, on validation mechanisms and on guidelines,in order to improve the accuracy and quality of such data. IHP-IX goes as far as committing to support the development of scientifically valid methods and tools that promote inclusive knowledge generation processes, such as citizens' contribution to scientific research. Training, in particular, will contribute to enhancing accuracy and validity of data. Scientific tools shouldbe developed to encourage citizen participation and other social applications that can improve water management, such as integrating modern science with ancestral, indigenous and local knowledge.

To add on future uptake of CS information, IHP-IX promises to create an enabling environment and assist citizens and scientists,through enhanced water knowledge and education programmes to ensure scientific methods are used when participating in and reporting their findings to increase the contribution of citizen science to hydrology research. The lesson plans produced by the WRC support the IHP-IX that water education must begin at an early stage in life and continue to be offered in a variety of ways to build a water stewardship mentality at all ages and in all communities, awakening critical and emancipatory awareness in citizens in relation to their rights and duties so that they can be active citizens. We must have a cadre of new scientists, planners, and practitioners equipped with skills for addressing complex interconnected water challenges and ready to assume positions of responsibility in a fourth industrial revolution setting in the water sector by the end of this decade.

Financing

Securing and optimizing sufficient financing for water quality monitoring is a major challenge for many countries with competing pressures on limited resources. Funding deficits impede implementation of water quality monitoring and assessment programmes, and result in gaps in the data record that can be difficult to fill. International standards to exchange water quality monitoring data, as well as aggregated indicator data, are lacking. However, in many other countries as well, it's not financial constraints, but policy support, will and priorities. As alluded to above, the private sector owes nature investments in restoration, while ordinary citizens owe nature time to care, clear alien invasive plants, clean rivers as Hennops revival NPO does and many more non-government friends of species. Therefore, some will invest financially, legislatively, others donate time, while others sponsor stewardship efforts.

Innovation

The toolbox (**WRC Report No. TT 763/18**) is based on simplified versions of the complicated scientific and high technical tools used by the DWS in authorizing the licenses, reserve determinations, EIAs, etc. They are used on physical encounter where CS are trained, and use of the tools demonstrated. However, the sudden outbreak of COVID:19 in 2019/2020 brought not only a halt on physical community engagement, increased risk of infection by the SARS-CoV-2 virus, but also meant no training nor sampling by the CS. Noting the risk of losing the relationship with communities, WRC is funding the migration of these tools to online availability, such as Videos, You-tube. This will be ready for use by 2023. This is because ground verification is required. According to Damania *et al.*, (2019 in UNEP 2021), the twenty-first century offers new and exciting opportunities for innovation in water quality monitoring and assessment. A good example is the triangle approach of in situ and remote sensing and modelled data, and machine learning approaches as demonstrated in the World Bank report, *Quality Unknown: The Invisible Water Crisis,* these approaches, coupled with advances in, and increased accessibility to, information communication technology (ICT) will help leverage and coordinate new and existing efforts towards achieving SDG 6. (UNEP, 2021) report shows a great interest and saw a huge potential in MiniSASS to close data gaps.

In-fact Bishop *et al.*, (2020 in UNEP 2021) notes that the biomonitoring approach developed in South Africa and in situ physico-chemical approaches shows that if properly designed and implemented, such initiatives can provide greater spatial coverage than traditional laboratory-based monitoring networks. These approaches, which involve citizen scientists in data-collection efforts, offer the additional benefit of promoting behavioural change and engaging citizens in water quality. The efficacy of these approaches is being tested further in a number of small-scale pilot initiatives in different world regions and the approaches will be supported by the creation of the Citizen Scientist 632 Toolbox within the SDG report. This Citizen Scientist 632 Toolbox will contain information and guidance on a range of tools that allow citizens to contribute to indicator 6.3.2 data collection while simultaneously learning about water quality management. The tools will vary in complexity, from observational measurements to advanced biomonitoring, and will enable citizens from a range of backgrounds and expertise to contribute. The toolbox will provide guidance and information on:

- physico-chemical data collection of nutrients, pH and turbidity
- biomonitoring data using macroinvertebrates and macrophytes
- observational information such as presence of smells, effluent inputs, algae growth and floating macrophyte coverage.

The toolbox could also be a two-way portal: besides offering citizens the opportunity to contribute to data collection, it could enable them to learn about their water body and the pressures in their catchment area.

Institutional support (especially policy) is essential to ensure that the data generated by citizens are incorporated into SDG 6 reporting, and that efforts to test the most appropriate mechanisms for combining regulatory and citizen data streams are ongoing.

Conclusion and recommendations

Several CS initiatives are being established in South Africa. Just within two years, covering 2020 and 2021, many webinars were held, some initiated by NGOs such as Partnership for Resilience through innovation and Integrated management of emergencies and disasters (PRIMEDIA) with a focus on experiences of community-driven disaster risks reduction, management and readiness. Others were led by UCT/Freshwater Research Centre consultancy, entitled “CS and biodiversity-why it matters-Rationale for conservation?”, a lecture led by the UJ-Dept of Geography, Environmental Management and Energy with a focus on water security/insecurity in Gauteng’s rivers and wetlands. Most recent was Mandela Day and a session in the WRC-50yr symposium, followed by the international best CS practises webinar, a joint effort by Waternet, UNICEF, WRC, and others. These are just but few examples of how popular CS is recently. South Africa has over 37 groups spread across the country. Unfortunately, these are all operating in silos, hence the urgent need to coordinate their efforts, not only in the country, but transboundary as well. The SADC Symposium, held in 2016, identified the need to establish a network of CS in order to have one solid and impactful voice. The next symposium is planned for May 2022 under the umbrella of the Society for Ecological Restoration-Africa Chapter. The chapter fully supports the UN decade call for ecosystem restoration, 2021-2030. SA as a signatory to SDG 2030, embraces this call and specific water sector related goals are under consideration, such as Goal No.6, 11, 14 and 15, as well as 17 on partnerships. Goal No.6 is like a central pillar for the rest of the goals to be realized. In the same breath, the Strategic Plan for the ninth phase of the Intergovernmental Hydrological Programme (IHP-IX) covering 2022-2029 identifies key water priority areas to support Member States to achieve Agenda 2030 (UNESCO IHP-IX), including:

- Reliable data is the most important basis for water resources management, without which implementation of decisions is severely handicapped. All analysis and modelling efforts are dependent on the quantity, quality, coverage, and accessibility of data. Data quantity should be maintained by reversing the current decline in the numbers of monitoring stations and sampling frequencies. Data quality determines the quality of scientific research outputs. The diversification of data sources allows scientific research to be based on larger and more complete data sets, increasing the confidence-levels of results. Scientific information should be combined with indigenous/local knowledge if available.

- Water data should not be limited to water quantity and quality parameters. Rather water use trends, and other human interactions with surface and groundwater should be monitored as well. Additionally, meta data are essential for data validation and should form an integral part of databases.

- Citizen science initiatives often times do not realize their full potential because of the limited reach of their efforts and the compatibility of the data collected. Solving these issues would lead to better science and sound policies on a larger implementation scale.To enable accurate interpretation of citizen science data, user-friendly platforms, outreach protocols, and capacity building exercises need to be developed to better inform NGOs and concerned citizens as to how to engage with decision makers more effectively.

- Public and private companies are also collecting data on the operation of the existing water infrastructure for various objectives. These data should ideally be posted in a publicly accessible database, at various jurisdictional scales, according to prevailing 'open access' policies of Member States. Investment by public, and in particular by beneficiaries, such as private sector needs to be encouraged and optimized.

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