Review of Human Impacts on the Hydrologic (Water) Cycle

Water is life, or expressions to this effect, are commonly reflected in many works of literature and other, more visual representations of its value (NOAA,2019; NASA, 2022; Vimeo, 2018). This essay discusses the basic information of what water is and how it is represented in the hydrologic cycle, its main reservoirs and exchange pools, human activities impacting on the cycle and a critical analysis of realistic solutions in terms of implementing those alleviation measures.

Ripl (2003, p. 1921) states that: “Water, the bloodstream of the biosphere, determines the sustainability of living systems.” but he further reasons that interference by humankind in the flow processes involved in the hydrologic cycle, such as the conversion of evapotranspiration processes and increased use of groundwater has proved to be adverse to sustainable life processes (ibid. p. 1922).

Therefore, the case for working towards understanding and learning how to provide greater resilience to the hydrologic cycle is of great significance.

What is water?

Water is a molecule consisting of three atoms, two of hydrogen and one of oxygen and can exist as a liquid, vapour and solid. Pure water is colourless, odourless and tasteless and is considered to be a universal solvent dissolving many naturally occurring substances (EMT, 2022). It is found in a multiplicity of locations but, in broad terms, constitutes about 71% of the Earth’s surface, 96.5% of which is found in the oceans and only 3.5% as freshwater and frozen water locked into glaciers and polar ice caps. However, the amount of freshwater that appears available to support terrestrial biosystems is approximately 0.7% and, as such, reflects the value that this relatively scarce resource holds for humanity (Williams, 2014).

It is the observation of Ma et al. (2015), however, that because of global warming and climatic variability, sufficient water necessary for survival via

dietary and agricultural requirements may be at threat owing to the amplification of the hydrologic cycle.

The hydrologic (water) cycle

This is the circulating water movement from land to the atmosphere and back to earth again. This “includes hydrological processes at all scales within the hydrosphere, and is driven by solar radiation and gravity (Yang et al.,2021) and as can be seen in Figure 1. and described by NOAA, 2019:

> It is a complex system that includes many different processes. Liquid water evaporates into water vapour, condenses to form clouds, and precipitates back to earth in the form of rain and snow. Water in different phases moves through the atmosphere (transportation). Liquid water flows across the land (runoff), into the ground (infiltration and percolation), and through the ground (groundwater). Groundwater moves into plants (plant uptake) and evaporates from plants into the atmosphere (transpiration). Solid ice and snow can turn directly into gas (sublimation). The opposite occurs when water vapour becomes solid (deposition).

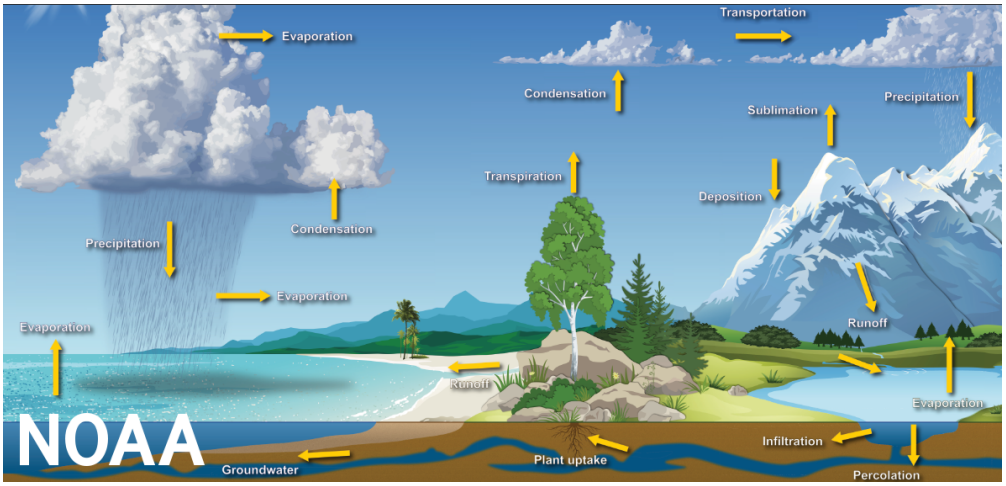

Figure1. The water (hydrologic) cycle (NOAA, 2019)

This further indicates that in-between phases of evaporation, precipitation, condensation, sublimation and transpiration, volumes of water remain contained in reservoirs. It is those reservoirs that humanity must use for consumption and seek to preserve to attain a sustainable future.

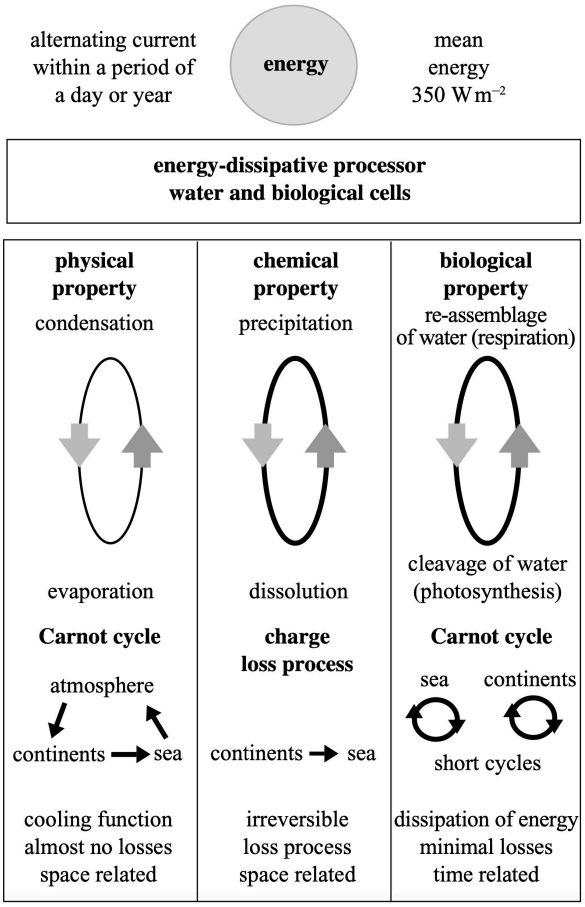

Figure 2: One estimate of global water distribution. Source: Gleick, P.H. (1996) Water resources. In Encyclopedia of Climate and Weather, ed. By S.H.Schneider, Oxford University Press, New York, vol.2, pp, 817-823.

Main reservoirs and exchange pools

As shown in Figure 2 below, water is contained in various locations, much of which does not give ready access for a community's consumption. For instance, the water retained in the atmosphere is not easily acquired as a potable source. Still, it can be described as an exchange pool, a significant, though temporary phase of the hydrologic cycle (Wilkin & Brainard, 2015). Many of these temporary phases are illustrated well in Figure 3. This indicates the physical, chemical and biological processes that represent their short cyclic time within the hydrologic cycle compared to the relative stability of major reservoirs. It can, however, give an understanding of the transfer of atmospheric pollution to subsequent phases in the hydrologic cycle.

Store	*Volume (1000 km^3)*	*Per cent of total water*	*Per cent of fresh water*
Oceans, seas and bays	1 338 000	96.5	–
Ice caps, glaciers and permanent snow	24 064	1.74	68.7
Groundwater	23 400	1.7	–
Fresh	(10 530)	(0.76)	30.1
Saline	(12 870)	(0.94)	–
Soil moisture	16.5	0.001	0.05
Ground ice and permafrost	300	0.022	0.86
Lakes	176.4	0.013	–
Fresh	(91.0)	(0.007)	0.26
Saline	(85.4)	(0.006)	–
Atmosphere	12.9	0.001	0.04
Swamp water	11.47	0.0008	0.03
Rivers	2.12	0.0002	0.006
Biological water	1.12	0.0001	0.003

Figure 3. Processor properties of water (Ripl & Hildmann 2000)

Those locations that offer larger volumes of water for biotic consumption are the oceans, seas, bays, groundwater and lakes (fresh and saline). Saline volumes are not immediately potable other than through desalination plants. These have been growing in popularity owing to water scarcity but have also produced their own environmental problems; the prime concern is the toxic effect of brine waste, a result of which, in a recent study, indicates a problem being grossly underestimated (Robbins, 2019)

Human activities impacting the cycle

Other main reservoirs that can be more readily exploited for human or agricultural consumption are lakes, rivers, dams and groundwater. In many geographic locations, dams have been constructed to ensure sufficient water for human communities and agricultural purposes, provide hydroelectric power, and control flooding. These also have environmental issues that impact the hydrologic cycle, causing problems such as the need for restoration of agricultural land, logging and forest clearing, erosion, groundwater level changes, and changes in animal and plant life (Akhmetshin and Kovalenko, 2019) and prevention of spawning sites for migratory fish (EEA, 2018).

Reconfiguring water pathways by dam construction can cause a range of impacts on the natural water cycle in any geographic region. Still, global warming through climate change also has a significant impact on alterations to the hydrologic cycle. Increasing global temperatures increase the rate of evaporation and precipitation rates and can lead to more rain, flooding and extreme drought (UCAR, 2022). This is commensurate with Betts et al. (2007), who averred that: “Increases in atmospheric CO2 concentration are impacting the terrestrial water cycle through changes in radiative forcings (affecting precipitation and temperature) as well as plant physiological and structural responses” The importance of this is:

> “terrestrial primary productivity through photosynthesis is the most fundamental ecosystem function not only because it provides the fuel that drives all other biological activities but also due to its significance in locking up carbon in biomass that would otherwise remain in the atmosphere as CO2” [Beer et al., 2010]

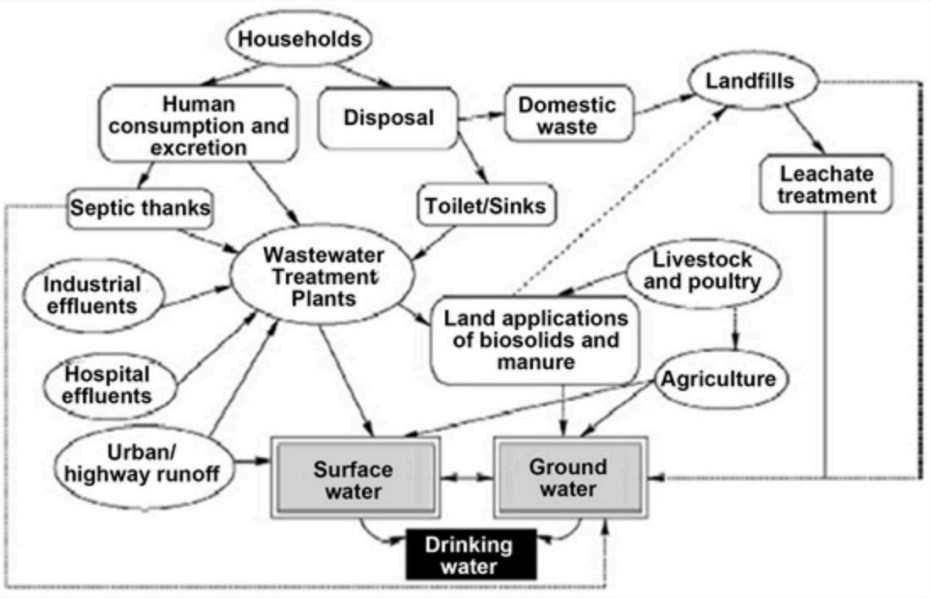

Figure 4. Possible water pollutant sources. Talabi and Kayode (2019) Groundwater Pollution and Remediation

Deforestation reduces biomass and not only destroys habitats but also severely impacts the hydrologic cycle by reducing the capability of evapotranspiration. As described by Derouin (2022):

> According to the United Nation's 2020 State of the World's Forests report, three-quarters of Earth's freshwater comes from forested watersheds, and the loss of trees can worsen water quality. The report also found that over half the global population relies on forested watersheds for their drinking water and water used for agriculture and industry.

This, in turn, may produce a decline in rainfall, creating drought-susceptible regions (Miller & Spoolman, 2020, p. 486).

Urbanisation also creates excessive ***groundwater abstraction*** leading to declines in water groundwater levels and land subsidence (Basu & Van Meter (2014), together with an increased likelihood of pollutant loading from domestic and commercial effluents (Lawrence and Foster, 1998).

Pollution in water sources is evidenced in all its forms; gaseous, liquid and solid. Pollution can be considered the primary problem of the hydrologic cycle in particular and the biosphere in general. In gaseous form, the greenhouse gases of CO2, CH4, N2O and fluorinated gases contribute to a considerable quantity of the emissions affecting the atmosphere; 6,558 million metric tons of CO2 equivalent in 2019 (EPA, 2021). This speeds up the effect they have on global warming and thus produces higher evaporation and precipitation rates creating regions that become susceptible to excessive drought and flooding (UCAR, 2022).

As Talabi and Kayode (2019) put it: "The impacts/effects of pollution on the Earth include environmental deterioration, impacts on the health of living organisms, global warming, depletion of the ozone layer and reduced efficiency or infertility of farm lands and crop fields."

In liquid form, pollution, as evidenced in water, reduces the availability of potable water and contributes to the degradation of local ecosystems, including the earlier mentioned groundwater supplies.

In solid form, Schneider (1973) avers: "That part of the hydrologic regimen associated with pollution from solid-waste disposal begins with precipitation

reaching the land surface and ends with the water reaching streams from either overland or sub-surface flow". As also noted by the City of Melbourne's Urban Water Notice (2022):

> When water comes in contact with urban surfaces such as roofs, roads and footpaths, it becomes contaminated with oil, metals, litter and other pollutants. Stormwater drains do not usually have any treatment systems, so pollutants are carried directly into our waterways, bays and oceans

Thus far, it is sufficient to see that humans do indeed affect the hydrologic cycle significantly, and concerning improving the less-than-optimal situation of this cycle, more consideration should be given to mitigation and adaptation practices to any existing, or, indeed, any future missteps.

What alleviation measures can be taken?

Adaptation to the impacts of increasing temperatures and variations in precipitation involves adjusting practices, processes, capital and infrastructure in response to actual or anticipated climate change (Craddock-Henry, 2017). Regarding agricultural concerns regarding the hydrologic cycle and its changing state, changes in policy and practice may include: agricultural diversification, reduced conversion of grassland to cropland, integrated water management, reduced deforestation, and soil erosion control (Smith et al., 2019)

About *Deforestation*, Hall (2013) avers: "Rainforest restoration holds much promise in helping to conserve biodiversity and ecosystem services, *but is not a substitute for preserving the intact forest.*" Also cited and paraphrased from the same source is that the restoration of deforested regions has been evidenced by passive or natural regeneration alongside active restoration (Lamb et al. 2005, Wright & Muller-Landau 2006, Chazdon 2008).

Success in the enterprise of reforestation would, at the least, improve the evapotranspiration phase of the hydrologic cycle and improve the cyclic flow of water to the atmosphere alongside other benefits of less soil erosion by unwanted floodwater and expansion of potential animal habitats.

Groundwater pollution reduces the number of potable water supplies. Problems associated with this could be addressed as Talabi and Kayode (2019) aver: “proper waste disposal, monitoring of hazardous materials, conducting environmental audit periodically and intensifying health education in addition, most pollution of groundwater is anthropocentric and can be prevented through intensive health education.”

The latter suggestion of education is vital regarding all environmental issues. This will ensure that populations know its significance to our overall well-being.

Critical analysis of realistic solutions in terms of implementing those alleviation measures.

Realistic solutions to any part of the hydrologic cycle must be met with the will and the courage to act. There has been a visible lack of real commitment to environmental concerns, including the hydrologic cycle and its importance, by many global governmental bodies compared to their concern for economic sustainability. This, in itself, can be considered ironic, in that ultimately, bank balances will be forced to realise the limits of tolerance the biosphere has had to endure; the essence of this statement is reflected by the Swiss Re Institute (2021) in their paper “ The economics of climate change; no action, not an option.”

An example of vacillation in this regard is the Productivity Commission of the Australian Government in their Research Paper titled: “Integrated Urban Water Management — Why a good idea seems hard to implement” (2020). This discusses many reasons why there is difficulty in providing an appropriate water infrastructure for its population. These reasons include “Roles and responsibilities for providing enhanced amenity are unclear”; “Stormwater planning and management is not integrated into general water planning”; “Restrictions and mandates prevent all options being put on the table”. These few sample topics of discussion in this report reflect a somewhat restricted (and discouraging) view of their Integrated Water Cycle Management (IWCM) vision by the apparent limiting of their discussion to urban scenarios and giving scant and vague reference only to the role-played and the ecosystems affected by, the non-urban environmental problems associated with the country’s total hydrologic cycle.

If the political will were to change and be enacted, permanent solutions could be provided by Government decision-making about primary issues that reflect on the entire hydrologic cycle; this would ultimately reward the urban environment.

In the short term, however, possible solutions that may warrant realistic solutions specifically aimed directly at phases of the hydrologic cycle, although also appearing amenable to those governmental authorities that should be taking the lead, are probably more likely to be pursued by individuals and NGOs who appear to be more accepting of the consensus of scientific thinking and are attempting to do something about it.

Realistic Solutions for mitigation of Water Cycle disturbances

The problems discussed earlier that presently cause disturbances to flows of the hydrologic cycle may be mitigated by the following steps:

Agricultural water usage: Managing livestock access to streams, this assists in keeping waste out of streams and keeps nitrogenous and phosphoric compounds out of the water and assists in protecting stream banks; optimisation of water utilisation by farmers using the WaPOR (Water Productivity through Open access of Remotely sensed derived data, EPA, 2021), reduce the area of crops and/or switch to alternate crops that demand less water.

Deforestation: Banning clear-cutting of forests; reforestation; reducing consumption of paper. Have citizen scientists group together in local regions such as “Tree Force” in Cairns, Queensland. This particular group uses local academics and arborists from the local community to improve reforestation and protection of the adjacent waterways from pollution.

Groundwater: Use less water; this can be voluntary or advised by local or government regulation; reduce the use of chemicals - for example, weed by hand and do not use herbicides; find alternative sources of water - an example could be the use of a rainwater tank to save rainfall that would otherwise be lost from gutter runoff.

Pollution: Wastewater treatment and recycling; water-efficient toilets; use of septic tanks; avoid using toilets for waste paper, cloths or other items. This interferes with sewage lines and subsequent treatment processes; shorter showers.

Conclusion

This discussion has covered only some of the issues affecting the hydrologic cycle, the greatest disturbance to this cycle being the excessive production of unwanted greenhouse gases. This is the “Elephant in our room” that appears to make all other adaptive and mitigation activities somewhat secondary to its removal.

This subject can offer limitless research and study. This applies not only to scientists but to the public at large. In this regard, another great mitigator to all of our environmental problems would be more thorough education at all levels of training.

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