PART I

THE

NEW

MACRO PERSPECTIVE PROSPECTUS

Of

THE PROBLEM

We are killing ourselves because of our lack of safe (or any) sanitation for most people on earth. We are poisoning ourselves with flush toilets, which are the primary source of many human and environmental threats – including the looming big one – antibiotic resistant bacteria.

This is every bit the threat to our survival that climate change is.

Fossil fuels powered our ancestors out of manual labor and agrarian penury into the industrial age and urbanization. But the sudden growth of crowded cities spawned a commensurate explosion of fecal-oral diseases (diarrhea, typhoid, cholera, dysentery, polio and hepatitis). In order to control these terrible infectious diseases an enormous public infrastructure investment was made in centralized sewer and sanitation systems. This vast public effort in the early 20th century has been cited by the Center of Disease Control as our greatest achievement in public health – with direct positive health outcomes: an end to suffering enteric diseases and death; to long term benefits in everything from longevity to economic productivity; and a general sense of well-being and happiness. An aside here: it seems it is human nature to reach for dazzling new accomplishments while ignoring unmet basic needs. Orville Wright almost died from typhoid fever in 1896 and typhoid killed his brother, Wilbur, sixteen years later.

Time changes everything. Fossil fuels, once hailed as the very burning heart of progress, are now reviled as the leading cause of air pollution and climate change. Centralized sanitation and sewers, once considered the greatest achievement of public health; we now realize are not only terribly expensive in terms of direct costs but in external costs as well – they are responsible for contaminating surface and tap water,leading to serious environmental and health consequences.

Just as in the past, it is energy that is leading the way into a new age. Sanitation will certainly follow out of sheer necessity – just as it did a century ago. Clean energy – solar panels, windmills and electric cars are the sexy, attention grabbing, shiny, new objects. At first glance toilets can't compete. (But that's just because people haven't experienced our new, sleek, waterless, *odorless* toilets and urinals yet.)

OUR MOST BASIC NEED IS STILL UNMET

55% of us on earth lack safe or even basic sanitation.
It is the leading cause of malnutrition, suffering, disease and death.

The overcrowded conditions in urban areas in the developing world today are similar to the plight suffered by the masses that flocked to cities over century ago in the global North. The massive investment in centralized sewers and sanitation in the early 20th century was not only necessary for improvement in public health; without it the continued economic growth experienced in Europe and North America could not have been sustained. A similar investment will be necessary now to foster economic growth of the global South. It is not for the want of effort but money. The health ministries of low-income nations are painfully aware of their need.

It is into this yawning need that Bill Gates boldly inserted his Foundation's money and influence in search of a "reinvented" toilet. Since 2012, when their *Reinvent the toilet Challenge* was announced, the Bill and Melinda Gates Foundation has poured $750 million hoping to prime the pump for innovative, investment ready toilet designs that according to a Boston Consulting Group analysis promise to become a $6 billion a year industry by 2030. A recent study published by the World Health Organization (WHO), found that for every $1.00 spent on safe sanitation in the developing world, $5.50 in economic growth should be expected. By those optimistic projections the Gates Foundation's original investment of $750 million would become $6 billion by 2030, which would eventually result in $33 billion in economic growth according to the WHO study.

Gates envisioned his quest to be similar to the evolution of computers from a few big IBM main frames to ubiquitous PCs. That worked so well for him earlier, why wouldn't the same happen again? The winners he chose for the initial Reinvent the Toilet Challenge competition in 2012 departed completely from existing composting toilet technology for instance, reflecting Gates' apparent preference for high-tech solutions. Many feared he may have missed the mark – too high tech to meet the need where it exists. One thing is certain however, he raised awareness and a lot of money.

The Gates Foundation has been joined by a whole host of investors to develop decentralized sanitation projects for low and middle-income nations. In Beijing at The Reinvented Toilet Expo in November 2018, it was announced that the World Bank, the Asian Development Bank, and the African Development Bank had committed to contribute $2.5 billion in combined funds to leverage development. The French Development Agency would double its annual contribution for sanitation development projects in developing countries to $683 million. The money is there. So, where are the toilets?

There were fourteen organizations from around the world touting their products at the Reinvented Toilet Expo. Four of the fourteen had already commercialized their products (very limited niche markets for installations in public spaces). Now, more than three years later those numbers are the same – ten are still works in progress. All fourteen have received significant additional funding for development. Most have teams of 20 or more scientists and engineers dedicated to developing their individual parts and processes. The toilet designs are very complex and far from being realized, much less commercially available. On the face of it, several of the designs seem unobtainable. Or, if all of the pieces do come together and were to work in concert as designed, because there are so many working parts, then maintenance and repair would certainly be an issue for years to come (never mind the cost).

The emphasis seems not to be on practical toilets for the real world but aspirational and very expensive excreta processing machines that are essentially miniature waste water treatment plants. Two are, in fact, described as omni-processors. There are no toilets attached. Sewage must be pumped to them just like sewage treatment plants, but on a smaller scale.

We are now well aware of the pitfalls of big centralized sewer systems and large-scale waste ("wasted") water treatment plants (WWTP). With sufficient investment in achievable technology, nations in the developing world can avoid those nightmares described in greater detail below and go straight to more efficient and beneficial decentralized sanitation, featuring waterless toilets and decidedly low-tech onsite water use systems that re-use graywater to irrigate trees. Our company's mission is to see this will be realized. It will be comparable to the way folks of the developing world were able to leap-frog the inefficient tangle of telephone land lines and go directly to cell or mobile phones. Ironically, a higher percentage of people in India now have cell phones than have access to safe sanitation, for instance.

It is perhaps not quite fair to equate the largest sprawling modern slums in the global South with the working-class barrios in the global North of yesteryear. The scale is not comparable, nor is the depth of the poverty. We are a working on a toilet specifically designed for use in public toilet blocks in these terribly destitute modern slums which will be far more comfortable and hygienic than those currently offered in those communities. And, they are practical for the conditions, not high-tech aspirations.

On the other hand, there are many communities throughout the developing world for which our three main products are very appropriate. These communities are populated by houses and apartments whose residents use latrines, or flush toilets that empty into holding tanks. Both the latrines and holding tanks must be emptied periodically by pump trucks at significant cost. The raw sewage is then applied on agricultural land. By the way, this practice is also commonplace throughout rural areas in the US where homeowners with fully compliant private septic systems (SS): septic tanks and drain-fields, are advised to empty their septic tanks periodically so that the sludge which settles in the tank doesn't displace too much of the volume of the tank and interfere with the flow or pumping into the drain-field. Land application, as it is called, is permitted and fully legal.

While on the topic of poor sanitation practices in rural America, it turns more than 2 million people live without safe sanitation. Sadly, like so many things (education, healthcare, income) lack of safe sanitation is defined by race – particularly in rural America. In a collaborative study conducted by the US Water Alliance, Dig Deep (a non-profit committed to providing water and sanitation to those among us without) and Michigan State University it was found that Native Americans are 19 times less likely to have safe sanitation than the population at large. Latinx and African American people are 5 times less likely to have safe amenities.[1]

In her recently published best-selling book, *Waste: One Woman's Fight Against America's Dirty Secret,* 2020 MacArthur Fellow, Jennifer Coleman Flowers, describes a hook worm outbreak in rural Lowndes County of Alabama where one in three inhabitants had been exposed to the fecal borne parasite. (Hook worm was thought to have been eradicated long ago in the US.)

Meanwhile 45% of us are committing *sewercide.* In the privileged or, *flushing world* the threats are merely invisible. Each flush emits a plume of fecally infused droplets. By abusing precious water to transport our excreta we are poisoning the planet. Everywhere in the flushing world contaminants are now found in measurable amounts in surface waters *and tap water*: unmetabolized pharmaceuticals, food additives, hormones – you name it. We call it – *sewercide!*

Flush toilets are not hygienic. Every time a toilet is flushed small bioaerosols (tiny droplets or spray) are emitted – more when the toilet seat-lid is open than when the lid is shut – but some of those bioaerosols still escape because the seat and lid are not airtight. In either case the bioaerosols readily mix with the air and can be inhaled, or they can land on surfaces and potentially be picked up by touch. Those bioaerosols may contain pathogens.[2]

Artificial sweeteners are used by researchers as a tracer compound to indicate the presence of other unmetabolized compounds etc. in water, which may co-indicate bio-accumulation as well. For instance, in a study conducted by Environment Canada (similar to the EPA in the US) and the University of Waterloo (located right in the middle of the study area) published in late 2013, found surprisingly high levels of all of the name brand artificial sweeteners in all Grand River

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[1] Rhadika Fox et al. "Closing the Water Gap in the United States – A National Action Plan" (source) as reported by: Frances S. Sellers, "It's almost 2020, and 2 million Americans still don't have running water, according to new report." *Washington Post.* Dec. 11, 2019 at 6:00 a.m. EST

[2] Johnson, David et al. "Aerosol Generation by Modern Flush Toilets." *Aerosol Science and Technology, Aerosol Science and Technology: The Journal of the American Association for Aerosol Research,* vol. 47,9 (2013)

water where samples were taken.[3] The Grand River flows into Lake Erie just upstream from Lake Ontario and Toronto. The city of Toronto gets its drinking water from Lake Ontario.

More ominously, in subsequent studies these same sweeteners were indeed found in drinking water supplies throughout the Grand River basin. These findings are not anomalous. Since then, similar test results have been found in studies elsewhere in the flushing-world.[4] What these studies have proven is that what is in our urine, from phosphorous to pharmaceuticals, flows right through us, and directly through our WWTP into our surface waters. Or in the case of SS; contaminants we ingest end up in our groundwater and from there to surface waters.[5] Not so sweet.

If we do nothing and continue to go on blithely flushing, nutrients, compounds, artificial sweeteners and all, will continue to accumulate in our water and eventually poison all aquatics *and* ourselves, one thoughtless flush at a time. That is why we call it *sewercide*. Or, we can save our water and ourselves with **NEW** toilets and urinals one waterless and odorless use at a time.

THE COSTS OF FLUSHING

1.) A PRIMARY SOURCE OF ANTIBIOTIC RESISTANT BACTERIA[6]

It's hard to ignore discussions of antibiotic resistant bacteria (ARB). It is a frightening topic. The World Health Organization: "Antibiotic resistance is one of the biggest threats to global health, food security, and development today." The specter of returning to the bad old days where common bacterial infections claim lives unabated seems a real possibility. Common knowledge has it that overuse of antibiotics is the cause. But how, exactly, does that result in ARB? It turns out, the 15,000 public WWTP and approximately 21-24 million SS in the US are essentially factories busily producing ARB. Here is how:

It has been well documented that antibiotics end up in our wasted water stream the same way artificial sweeteners do. As an example, sulfamethoxazole (SMX) is a very common antibiotic. Unmetabolized SMX is excreted in urine (mostly). It travels in flush-water through sewer lines to WWTP and SS. An extensive review of the problem by the US Geological Survey published in

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[3] Spoelstra, J et al. "Artificial Sweeteners in a Large Canadian River Reflect Human Consumption in Watershed". PloS ONE 8(12): e82706. Doi:10.1371/journal.pone.008276

[4] N. Perkola, P. Sainio. "Quantification of four artificial sweeteners in Finnish surface waters with isotope-dilution mass spectrometry." Environ. Pollut., 184 (2014), pp. 391 -396, 10.1016/j.envpol.2013.09.017

[5] John Spoelstra, Susan J. Brown. "Septic Systems contribute artificial sweeteners to streams through groundwater." https://doi.org/10.1016/j.hydroa.2020.100050

[6] Katariina M. M. Parnanen, Carlos Narciso-da-Rocha. "Antibiotic resistance In European wastewater treatment plants mirrors the pattern of clinical antibiotic resistance prevalence." *Science Advances* 27 Mar 2019: Vol.5, no. 3, eaau9124 DOI: 10. 1126/sciadv. Aau9124 *Introduction,* p. 1

2018 stated, "Previous studies have documented that SMX is a contaminant found in both U.S. streams and groundwater, and that wastewater treatment plants and septic tanks are sources of the antibiotic to the environment."[7]

Even before they reach the WWTP or SS bacteria and antibiotics come into contact with each other. Once they reach the WWTP they are mixed, macerated, pumped and processed in a giant, highly diverse stew. Numerous studies have shown that this environment is particularly conducive to the emergence of antibiotic resistant genes (ARG) that are shared across species of bacteria in a process known as horizontal gene transfer which is facilitated by plasmids or extracellular DNA.[8] [9] [10]

"One plasmid may carry resistance genes for several different types of antibiotics, resulting in positive correlations between one type of antibiotic and the resistance gene of another. This not only further complicates things but can be extremely dangerous. Because of their extremely small size – 1,000 times smaller than bacteria – free-floating plasmids can easily make it through filtration systems in the treatment process and exit the plant in the effluent,"[11] … and on into the receiving water unabated.

Furthermore, most WWTP have no means of removing any of the 100s of antibiotics, from wasted water. Many of these antibiotics stay suspended, evade filtration, and flow right out into the "receiving waters". The antibiotics contact natural bacteria in those receiving waters where they interact as they do in WWTP and SS. The various antibiotics may kill some bacteria and alter or change other species. Mutations in some bacteria begin to occur to adjust to the various antibiotic stressors in this quasi-natural environment just as they do in the WWTP and SS, via plasmids and ARG.[12]

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[7] Underwood, J.C. et al. "Effects of the antimicrobial sulfamethoxazole on groundwater bacterial enrichment": *Environmental Science and Technology,* v.45, no.7 p. 3096-3101 (from the U.S Department of the Interior, U.S. Geological Survey, June 27, 2018)

[8] Sivalingam, P.; Pote', J.; Prabakar, K. "Extracellular DNA (eDNA): Neglected and Potential Sources of Antibiotic Resistant Genes (ARGs) in the Aquatic Environments. *Pathogens.* 2020, *9,* 874. https://doi.org/10.3390/pathogens911108874

[9] Barancheshme, F., Munir, M. "Development of Antibiotic Resistance in Wastewater Treatment Plants" May 2,2019. DOI:10.5772/intechopen.81538

[10] University of Southern California, "Antibiotic Resistance is Spreading from Wastewater Treatment Plants." Science Daily. Science Daily, 6, March, 2019. **Journal reference:** Ali Zarei-Baygi et al. "Evaluating Antibiotic Resistance **C**orrelations with Antibiotic Exposure Conditions in Anaerobic Membrane Bioreactors, 2019. DOI: 10.1021/acs.est.9b00798

[11] Ibid.

[12] Nour Fouz et al. "The Contribution of Wastewater to the Transmission of Antimicrobial Resistance in the Environment: Implications of Mass Gathering Settings." *Tropical Medicine and Infectious Disease.* 25 February 2020

A large portion of the antibiotics, ARG, plasmids etc. entering the WWTP also end up mixed into the sewer sludge (the gunk that settles to the bottom of tanks and ponds at WWTP).[13] What to do with sludge is a major headache for the civil engineers that design and manage WWTP. About a third of the total electrical energy consumed at your local WWTP is by sludge manipulation. It has to be dewatered and treated. The US produces 13.8 million tons of sewer sludge (dry weight) annually. 15% is incinerated. 38% ends up in landfills. 45% is surface applied on agricultural fields.[14] This means that even more contaminants (antibiotics, ARB, ARG and plasmids among them) inevitably get carried by runoff from landfills and ag fields into surface waters, adding to the creation of ARG and resultant ARB.

Many studies have documented that agricultural or veterinary use (or to be more precise, overuse) of antibiotics also contributes to the escape of unmetabolized antibiotics and dissemination of antibiotic resistance genes into the environment where, again, water, the universal solvent, is the medium of transport.[15] To be sure though, WWTP and SS are the primary culprit/contributor by a wide margin.

According to the EPA about 21% of the households (61 million people) in the US are served by SS. They are regulated by a combination of state, county and local jurisdictions and agencies. Because of their sheer number and wide geographical distribution, regulation and oversight for the estimated 21-24 million SS cannot come close to what exists for WWTP. Nor have they been studied on a scale anything close to that of WWTP. Estimates as to how many might be out of compliance (failing to protect groundwater and surface water) vary widely from state to state (15 – 35%). Suffice it say that there is a very high probability that SS contribute more on a volume of use basis to pollution and ARB than do WWTP. One study, led by the intrepid Dr. John Spoelstra of the University of Waterloo (cited above) elucidates the flow of artificial sweeteners from SS to ground water to streams in the Grand River basin of Ottowa, Canada. That study probably typifies the conditions of SS found throughout North America and around the world.

2.) WATER SCARCITY CRISIS[16]

Fresh water is a finite resource. Our water use is outstripping our supply at an ever-increasing rate. It is a crisis every bit as alarming as climate change (in fact they are interrelated parts of the same threat to our survival). The only difference is that the water crisis is (as yet) for the most

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[13] Yoo, K., Yoo, H., Lee, J. et al. "Exploring the antibiotic resistome in activated sludge and anaerobic digestion sludge in an urban wastewater treatment plant via metagenomic analysis. *J Microbiol.* **58,** 123-130 (2020), https://doi.org/10.1007/s12275-020-9309-y

[14] Center for Sustainable Systems. University of Michigan. 2020. "U.S. Wastewater Treatment Factsheet"

[15] Adriana Osinska, Iwona Konopka. "Small-scale wastewater treatment plants as a source of the dissemination of antibiotic genes in the aquatic environment." *Journal of Hazardous Materials.* Volume 381, 5 January 2020, 121221

[16] Note: The information under this topic has been derived from the following three sources: studies, reports and factsheets produced by the US Geological Survey (USGS), the Environmental Protection Agency (EPA), the United States Department of Agriculture (USDA) and various organizations whose original sources are also the USGS, USDA and the EPA.

part out of sight. It is for the moment not as dramatic as climate change. Or perhaps it is out of the spotlight because climate change just happens to be in the eye of a media storm.

The estimated total daily water usage in the US is currently 345 billion gallons (for everything from irrigation to toothbrushing). Personal domestic use (80 – 100 gallons/person/day) comprises about 10% of the total consumption at 32 – 34 billion gallons daily. Flushing wastes 24 – 30% of the personal water use (8 – 10 billion gallons every day in the US). WWTP treat 62.5 billion gallons of wastewater daily, which is almost twice the amount produced by households alone. SS receive 5.5 – 6 billion gallons daily.

Significant groundwater/surface-water depletion is irreversible if current practices are not changed. When water is used and ends up in WWTP it is discharged to rivers and ultimately flows at the rate of 62.5 billion gallons per day to the sea. That is 62.5 billion gallons a day that will never replenish our groundwater. Ostensibly, in rural areas water is being drawn from private wells and after it is used in homes it *will* eventually recharge groundwater at the rate of 5.5 – 6 billion gallons a day nationally. However, as illustrated above, that water will carry contaminants that will, in the best of circumstances, merely compromise groundwater quality in the immediate area of the drain-field – and not the well water on the property.

To make matters worse, in rural agricultural areas, two pressures related to water shortages are converging, especially in dryer regions that rely on irrigation. Pressure for irrigation is causing groundwater depletion. Using the nutrient rich water from WWTP for irrigation is seen as a “win-win” alternative solution. This would add another polluting burden to the land and water in rural areas. Agricultural land is already the repository for sewer sludge from WWTP. WWTP receive a vast array of contaminants from industrial sources that are far more concentrated and harmful than mere household effluents e.g. medical wastes, heavy metal residues, and nano-sized plastic particulates not to mention all of the pharmaceuticals, ARB and ARG etc. discussed above.

Keep in mind we have been discussing the water scarcity crisis with a focus on the United States. There are better conditions around the planet. But for the most part, in populated areas things are even worse – far worse in some nations. Finally, without fundamental changes in water use, as the population grows so will the crisis of water scarcity.

3.) NUTRIENT OVERLOADING = DESTRUCTION OF AQUATIC LIFE

Human excreta contain three elements that are essential nutrients for all forms of life: nitrogen (N), phosphorus (P) and potassium (K). Urine contains most of the nutrients: N - 90%, P - 70%, and K - 85% (feces: N - 10%, P - 30% and K - 15%).[17] Human excreta contributes 50 – 90% of these three nutrients that end up in the wasted water in WWTP and SS. Despite their potential

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[17] C. Rose, A. Parker, B. Jefferson, E. Cartmell, “The Characterization of Feces and Urine: A Review of the Literature to Inform Advanced Treatment Technology “. *Critical Reviews in Environmental Science and Technology”* 2015 Sep

as fertilizers a very small portion of NPK are recovered by processes in WWTP and almost 0% by SS.[18]

“Eutrophication accounts for the foremost aquatic ecosystem management problems in rivers, lakes and estuaries around the world. Eutrophication is caused by N and P nutrient loading of surface water…Impacts are not restricted to fresh water, since coastal seas are also affected by eutrophication, ultimately leading to harmful algal blooms and hypoxia due to the decay of algal biomass.”[19] P is often regarded as the primary source of algal blooms leading to subsequent eutrophication, generalized hypoxia and finally, ”dead zones”.[20] “The two most important sources of nutrients in freshwater systems are nutrient losses from agriculture and wastewater discharge from households and industry. In many countries, households are the main point sources of nutrients…”[21]

In the US the problem of N (in coastal areas) and P (particularly in freshwater watersheds) entering waterways is in most cases worse on a per capita basis in rural, agricultural and exurban areas for three reasons.

The first reason is the most visible; agricultural runoff from fertilizers. Top dressing of fields with livestock manure, and sewer sludge from WWTP is visible but, as with everything having to do with wasted water, it’s what is out of sight that really hurts us. **Human sewage from WWTP and SS contribute 70% of the P entering surface waters, and 30% from agricultural run-off.[22]** And, most of that 30% is not the visible and malodorous manure and sewer sludge but from commercial P fertilizer application.

If plants don’t have enough available P they can’t survive, much less flourish. Often called rock phosphate or phosphate rock, phosphorite is the source of most P fertilizers. Where phosphorite occurs naturally in sedimentary deposits of high enough P content that is readily extractable, it gets mined and processed into fertilizers. The mined rock gets smashed and pulverized into its rawest form. The P content in this form is only about 30% and not optimal for root uptake. It must be further processed and chemically engineered or, in the industry’s coined parlance, “beneficiated” (chemically engineered) at considerable cost to be a *fairly* efficient fertilizer.[23]

2: 45(17): 1827 – 1879. DOI: 10:1080/10643389.2014.1000761 PMC: United States Library of Medicine,National Institutes of Health.

[18] P.J.T.M. van Puiijenbroek, A.H.W. Beusen, A.F. Bouwman “Global nitrogen and phosphorous in urban waste water based on shared socio-economic pathways”. *Journal of Environmental Management* Volume 231, February 1, 2019, pages 446 - 456 https://doi.org/10.1016/j.jenvman.2018.10.048

[19] Ibid: P.J.T.M. van Puiijenbroek et al. 2018

[20] Higgins, Scott N. et al. “Biological Nitrogen Fixation Prevents the Response of a Eutrophic Lake to Reduced Loading of Nitrogen: Evidence from a 46-Year Whole-Lake Experiment”. *Ecosystems.* **21** (6):1088-1100. DOI:10.1007/s10021-017-0204-2. S2CID 26030685.

[21] Ibid: P.J.T.M. van Puiijenbroek et al. 2018

[22] Bowes, M.J. et al. “Characterizing phosphorus and nitrate inputs to a rural river using high-frequency concentration-flow relationships.” *Sci.Total Environ. 511, 608 – 620.* DOI:10.1016/j.scitotnv.2014.12.086

[23] Kaiser, D., Pagliari, P. “Understanding phosphorous fertilizers.” *University of Minnesota Extension Service.* Reviewed in 2018.

P has a propensity to attach to many different forms of soil particles which can to be carried by water in either particulates or dissolved forms which makes P highly prone to runoff.[24] To compound this problem, minable phosphorite is in a global scarcity crisis of its own, and it is *serious*.[25] This will be discussed in greater detail in regards to utilizing P in its ionic form so it can be readily and immediately assimilated by root hairs – in the form of stored undiluted human urine which is free and endlessly renewable. No runoff. No ruined water. No "dead zones".

The second reason is that rural areas are mostly "served" by SS. In a properly functioning SS, 90% of the N (found in urine) is readily converted to ammonia in the septic tank. The ammonia is then volatilized so the N (along with all the other putrid greenhouse gasses created by the anaerobic conditions in the tank) simply escapes into the atmosphere because septic tanks must be vented. (Which, of course, is a major greenhouse gas source.) Some of the N and P in feces settle in the tank, and in general don't pose a threat to surface water.

A study conducted by the University of Florida IFAS Extension found that most of the P in our pee stays suspended and flows into the drain-field. If the soil utilized in construction of the drain-field is of the right sort, much of the P is captured by soil particles; consumed by microbial action; and converted by chemical reaction. However, after a period of time the soil column beneath the drain-field becomes saturated and shallow ground water tables (most of Florida) develop P plumes. Because shallow groundwater flows towards surface waters P subsequently reaches surface water.[26] In 2017 approximately 31% of the population in Florida rely on septic systems to treat household water.

As mentioned earlier, because of their inherently wide geographical distribution SS are not studied nor inspected closely. Inadequate sewage treatment may be more the norm than the exception. Outright failure rates are estimated to be as high 10 – 20% nationally and much higher locally. Witness the work of MacArthur Fellow, Jennifer Coleman Flowers. She found in that in Lowndes County in Alabama somewhere between 40 and 90% of the households had failing septic systems – or none at all.

Dr. Joan Rose, Professor of Microbiology at Michigan State University in the Department of Plant, Soil and Microbiological Science; Homer Nowlin Endowed Chair in Water Research; Co-Director, Center of Water Sciences and Center for Advancing Microbial Risk Assessment and 2016

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[24] Reid, K., Schneider, K., McConkey, B. "Components of Phosphorus Loss from Agricultural Landscapes and How to Incorporate Them Into Risk Assessment Tools". *Frontiers in Earth Science Marine Biogeochemistry* 05 September 2018 I https://DOI.org/10.3389/feart.2018.00135

[25] Dana Cordell "The Story of Phosphorus: Sustainability implications of global phosphorus scarcity for food security" *Department of Water and Environmental Studies* Linkoping University Press 58183 Linkoping University Linkoping Sweden

[26] Mary Lusk, Gurpal S. Toor, Tom Orbeza. "Onsite Sewage Treatment and Disposal Systems: Phosphorus" *Publication SL 349: Soil and Water Science Department, University of Florida IFAS Extension* Reviewed October 2017

Stockholm Water Prize Laureate set out to study eutrophication of surface water in 64 watersheds in Michigan's Lower Peninsula five years ago. She found a lot of human based pollution. It became clear the source was SS.

Rose discovered that even "working" SS weren't filtering out the pollution they were designed to keep out of surface waters. "We used to think that once [waste] goes into a soil we don't have a risk" she commented. "We realize now that there are many, many contaminants that move through the soil: viruses, nutrients and even bacteria."[27] As Jennifer Coleman Flowers noted about her County in Alabama, "It's not just a regional issue. These crises are happening across the U.S."

Let's look at Long Island. Where too much P is particularly harmful to freshwater; overloading coastal waters with N is especially deleterious.[28]

When a SS is functioning properly, N (as ammonia) is "only" harmful as it escapes to our atmosphere. It is only when there is a serious malfunction in the SS where N reaches groundwater and from there migrates to surface water (or, in this case) to coastal water. Suffolk County on Long Island is the home to 1.5 million people and about 365,000 failed SS under which a large N plume has formed in the groundwater. Over the past 4 decades the plume has infiltrated Long Island Sound to such an extent that algae blooms have closed beaches. The N pollution has all but killed off the once famous clamming industry.

The people of Suffolk County have started to react but only after serious damage has been sustained. The state and federal government have contributed grants to rebuild after Hurricane Sandy and property owners have begun install new SS utilizing the matching grants provided to assist them. Steve Bellone, the county executive, summed it up this way, "The problem with septic systems is that they're underground. The saying 'out of sight out of mind' is apt here. When people buy their houses they know how old the boiler is, how old the roof is. They don't know how old their septic system is or how it's working. But we're really starting to see the results of [failed] septic systems: closed beaches, red tide, brown tide, fish kills." [29]

The third reason is that it is very (or too) costly for rural WWTP to retrofit their facilities in order to reduce the levels of P, the most problematic nutrient, from their discharge effluents. A study conducted by the School of Engineering at Newcastle University in the UK summed it up best: "The removal of [P] from domestic wastewater is primarily to reduce the potential for

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[27] Daniel C. Vock. "America has a Sewage Problem." *Infrastructure & Environment.* Published by Governing.com February 26, 2019

[28] Robert W. Howarth, et al. "Nutrient pollution of coastal rivers, bays and seas." *Issues in Ecology* no.7 USGS_PW_70174406.ris

[29] Daniel C. Vock, "America has a Sewage Problem." *Infrastructure and the Environment.* Published by Governing.com. February, 26 2019

eutrophication in receiving waters, and it is mandated and common in many countries. However, most P removal technologies have been developed for use at larger waste water treatment plants that have economies-of-scale, rigorous monitoring, and in-house expertise. Smaller plants often do not have these luxuries…"[30]

According to the same study, it isn't just a matter of cost that would make most of the P removal methods employed by larger WWTP out of reach for many rural jurisdictions, it would often be impossible because there simply wouldn't be enough space to expand the operations to accommodate various possible methods.

Apparently, the small town of Windom, Minnesota had the space to make the necessary improvements to its WWTP to comply with EPA effluent limits. And, the community of 4,428 residents was able to put an impressive funding package together with considerable help from various state and federal sources and guidance from the umbrella organization, the Minnesota Public Facilities Authority. Since this unique water and sewer infrastructure funding program began a few years ago, over 150 community projects have been enabled in Minnesota.

The Windom project serves as an example of the real costs for a WWTP to effectively reduce the nutrient levels of the effluents it discharges to receiving waters. These major improvements only address the nutrient problem -- ARB, unmetabolized pharmaceuticals, contamination from other unfiltered chemicals and nano-particulates remain unresolved.

According to the official website for the City, Windom-mn.com, the wastewater treatment plant was built in 1995 for $4.1 million ($7.1 million in today's dollars). It was upgraded in 2012 at a cost of $2.6 million ($3 million today) totaling $10.1 million, amortized over a 24-year period until 2019. The City of Windom had not been negligent or neglectful of waste water management.

On January 2, 2019 the city announced: "The City of Windom has undertaken a comprehensive improvement project at its Wastewater Treatment Plant. The City has secured public funding for this project that will reduce the nitrogen and phosphorus content of its effluent to better serve the residents and businesses of the City of Windom. The contract for the improvement was awarded on January 2, 2019 in the amount of $18,941,979." The improvement is a capital allocation of $13,265 for each household. This does not include the average $721/year assessed to each household for sewer service.

Windom is a window on what we can expect to see repeated in small towns all across the flushing world just to get effluent nutrient levels down far enough to *limit* eutrophication. It will very be expensive, but it is just a down payment. Again, eutrophication, red tides and fish kills are visible. Bio-accumulation of contaminants and ARB are not. But, that does not mean they are not caused

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[30] Joshua T. Bunce et al. "A Review of Phosphorus Removal Technologies and Their Applicability to Small-Scale Domestic Wastewater Treatment Systems." *Frontiers in Environmental Science Waster Management* 22 February 2018 https://doi.org/10.3389/fenvs.2018.00008-

by flushing. The rational thing for us to do would be to keep our excreta out of our water in the first place. Flush toilets are the very definition of point source pollution.

Windom is located in the middle of a very productive agricultural region. Farmers there, like everywhere in the world's breadbasket, buy and apply petroleum based anhydrous ammonia (which is explosive and corrosive) to meet the N needs of the crops they grow. They also buy and apply chemically enhanced P. Both sources for these fertilizers don't exist in Minnesota. Phosphorite, the source for the P fertilizer, is mined in Morocco before it gets "beneficiated" so it can be utilized by the corn and soy beans growing around Windom. The K comes from Canada. It has to be chemically enhanced too.

At least 80% of the N and P removed by the nearly $19 million upgrade at the Windom WWTP comes from flush toilets in town (mostly from urine). That urine not only contains the N, P and K (all in ionic form – just ready to be absorbed by the root hairs of the crops local farmers grow) but it has magnesium, calcium, sulfur and other micro-nutrients which are readily available without factory enhancements either. As we will learn, human urine is an excellent fertilizer.

4.) CARBON BIGFOOT[31]

800,000 miles of public sewer lines are fed by 500,000 miles of lateral pipes that connect private homes and businesses to the public lines. The sewage flow is assisted by pump stations until it arrives at some 15,000 WWTP in small towns and big cities throughout the nation. That's where real action begins. Typically, all of the sewage is first forced/pumped through screen into a grit removal/settling tank. Then it is pumped to a primary clarifying (settling tank; pumped again to a big tank where the sludge gets activated (mixed by giant rotating arms).

The sludge then is separated and pumped to a digestion tank creating methane from which gas is collected and blown into a separate tank where it is pressurized. The gas is burned in larger, more modern plants, to create some of the energy used for plant machinations. In the smaller, older and less sophisticated plants the methane is merely flared. **Worse, in many WWTP the methane, hydrogen sulfide, and other anaerobic off-gasses just escape into the atmosphere**. The sludge gets pumped to a dewatering plant where giant centrifuges dry the sludge before it is heated and finally gets removed. Some of It is hauled, up to 100 miles where the sludge gets spread out on ag fields. The remainder is dumped in landfills or incinerated.

Back on the liquid side, the emerging clarified effluent water is siphoned or pumped through several more settling ponds. Sludge from these ponds is trucked to landfills. The clarified water is filtered and disinfected with chlorine. The chlorine is removed and the remaining effluent is

[31] Note: The information under this topic has been derived from the following three sources: studies, reports and factsheets produced by the United States Geological Survey (USGS), the Environmental Protection Agency (EPA), the United States Department of Agriculture (USDA) and various organizations whose original sources are also the USGS, EPA and USDA.

pumped out to the river or "receiving water." **The entire process consumes an estimated 2-3% of all the electricity produced annually in the US.**

That estimate does not include the energy consumed nor the costs associated with removal of the sludge to landfills, incineration or agricultural land application. The overall cost of this sludge handling is estimated to be $400/ton[32] (for a typical WWTP > 100,000 population service district) or $5.5 billion per year in the US.

It is clear that if we continue to operate WWTP more aggressive end filtration will be required in order to avoid serious public health consequences. In fact, any serious read of the section on ARB should lead one to conclude aggressive filtration should be implemented immediately. This will require even more power than is currently being used in our WWTP. Any rational person would also conclude we must begin replacing flush toilets with **NEW** waterless toilets and urinals – TODAY.

5.) OPERATING AND MAINTENANCE COSTS[33]

The costs for all US municipalities to operate WWTP (for sewer districts serving over 100,00 people) in 2016 was estimated to be more than $50 billion/year.[34] That is roughly $189 per person ($756 per household of four). The average annual water and sewer bill per household of four across the US is $1248 ($756 for sewer and $492 for water.)

There is a big caveat here. The crumbling infrastructure factor. The dramatic bridge collapse in Minneapolis and the lead water pipes in Flint are just canaries. Small cities and towns in rural areas are not included in this cost analysis. See the previous section for an insight into those costs in the discussion of the Windom, Minnesota example.

Municipalities across the US have requested aid from the federal government to the tune of $271 billion[35] to make needed repairs and updates to sewers and WWTP. That amounts to $1027 per person or $4,108 per household. These are costs that must be borne for those 79% of Americans who are served by WWTP. If this capital cost was amortized over a 15-year period the cost would be $273/year for every household. With those capital expenditures factored in **the average water**

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[32] MWRD, "Metropolitan Water Reclamation District 2018 Final Budget Adopted December 14, 2017 and Amended (2018) accessed 10/29/2018 https://mwrd.org/sites/default/files/documents/2018_Final_Budget.pdf, Accessed 21st Dec 2017 Google Scholar

[33] Ibid: Primary sources USGS, EPA and USDA publications.

[34] USCOM, "Local Government Investment in Public Water and Sewer Hits a Record $123.7 Billion in 2016" *United States Conference of Mayors (USCOM)* 2018 Washington D.C. http://www.usmayors.org/wp-content/uploads/2018/10/2016-Spend-Article.pdf Google Scholar

[35] EPA, "Clean Watersheds Needs Survey 2012: Report to Congress" *U.S. Environmental Protection Agency* Washington D.C. (2016) EPA-830-R-15005 https://www.epa.gov/sites/production/files/2015-12/documents/cwns_2012_report_to_congress-508-0pt.pdf Google Scholar

and sewer cost for a household of four is $1,521/year served by a WWTP (with a service district over 100,000 people in the US).

What about the 21% (69 million) who use septic systems? An “average” cost estimate for SS will be even more difficult to come up with for a household of 4, because soil conditions and water table depth determine the type of drain-field required. That is a variable cost which is all over the place (geographically speaking).

This will be a very hypothetical case. Let’s assume a new septic system is installed at a cost of $12,000. The tank itself costs $2,000 including its installation. The tank, especially concrete tanks, could be expected to last 30 years or longer. The drain-field construction in this hypothetical case costs $10,000. With proper maintenance, a system can last at least 15 years.[36] Proper maintenance, in this case, requires pumping the septic tank every 3 years costing $400, or $2,000 over the life of the system. The electrical power cost of running a submersible pump for flushing, and 25% of the cost of the pump itself (that portion of the cost designated for flushing) adds an additional $1,700 over the 15-year period. The total expenditure over 15 years: tank, $1,000 (1/2 of the 30-year expected service life); drain-field, $10,000; tank pumping, $2,000; electricity for the well pump, $1,700. The total cost is $14,700. **The average cost for a household of four living in the US is $980/year to use and maintain a SS.**

CONCLUSION

The problem and need are universal but not identical for all people on earth. In the South, or developing world (and for 2 million people in North America) the problems are much more immediate and urgent. Parasites and fecal-oral diseases weaken and kill people. Lack of sanitation thwarts economic development.

In the *flushing world* it’s a slower and out-of-sight killer **–** it’s **sewercide.** This may change if antibiotic resistance snowballs – which it well may. What has been shown is that a flush toilets are either ***the*** source, or are major contributor to many problems we face: ARB; pharmaceuticals and other contaminants in our waters; water scarcity; ruination of aquatic life; greenhouse gas emissions, energy consumption; and they are becoming an exorbitant expense.

They are the epitome of an out-dated old way that are slowly but surely killing us. Like smoking cigarettes, flush toilets are a bad smelly old habit we need to quit. Life will be so much better without them.

But, it’s more than that. Next, we will learn that the **NEW** toilets and urinals will not only solve the problems, meet and exceed the needs we have discussed, but they will provide a panoply of positive, pleasant and well-intended consequences.

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[36] EPA, “How to Care for Your Septic System” *United States Environmental Protection Agency* Septic Systems