Greywater pollution

Short description of how pollution is measured -- primary and secondary pollution.

Primary pollution
Historically speaking, it was not so very long ago that lakes, rivers and coastal waters were clean and supported a balanced aquatic plant and animal life. As rivers and lakes started to receive organic pollution from industry, sewers, septic systems, and present -day agricultural and livestock-raising practices, these organics decomposed in the water, consuming the oxygen dissolved in it--oxygen crucial for fish and other aquatic animals. This process is known as primary pollution. The commonly used measurement of primary pollution is BOD5 (five-day Biological Oxygen Demand) and COD (Chemical Oxygen Demand)--the amount of oxygen extracted from water by bacteria when pollutants decompose. The more organic material there is in sewage, the greater the amount of oxygen needed to decompose these pollutants and, consequently, the greater the primary pollution.

Secondary pollution
Concommitant with the primary pollution, algae and other "out -of- balance" plant species start to grow as the result of being fertilized by the surge of nutrients from the above-mentioned sources. These fertilized plants, in turn, die and decompose, further robbing the water of its naturally dissolved oxygen. This phase is called secondary pollution (Diagram A), or "eutrophication", and is considerably more damaging to the oxygen level than primary pollution. The principal nutrients causing secondary pollution are nitrogen, phosphorous and potassium. Secondary pollution is measured by how much fertilizer is added to water. To understand their growth potential in water, it is necessary to know which nutrients in it are in short supply in the water. Some lakes are growth-restricted by the lack of phosphorous, others by lack of nitrogen and others, yet again, by the lack of potassium.

Generally speaking, combined sewage is rich in all three nutrients and contributes greatly to unbalanced plant growth in water, be it in a lake, a stream, or an estuary. We also need to see how nutrients are most likely to reach bodies of water -- direct discharge of sewage adds all the nutrients whereas soil infiltration systems primarily add nitrogen which freely travles with the water. In contrast, phosphorous has a propensity for locking on to soil particles by ion-exchange and does not travel to pollute nearby waters as readily.

The diagram below gives a rough idea of primary and secondary pollution derived from flush-toilets and various greywater sources.

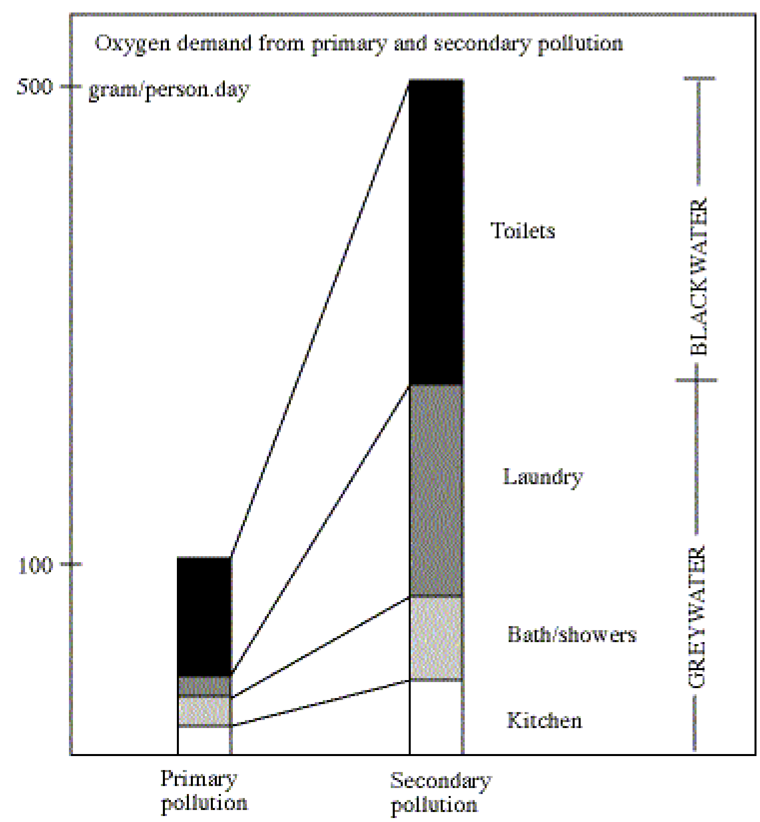


DIAGRAM A.

What distinguishes greywater from blackwater?

Greywater(washwater) sources are found in the kitchen, the laundry, bathrooms/washrooms, sinks, and showers. None of these sources carries water which is likely to contain disease organisms of anywhere the same magnitude as those in toilet wastes. By far the greatest source of pathogens in wastewater is excrement. Urine is sterile save in exceptional circumstances (e.g., grave urinary tract infections). In households with infants in diapers, fecal matter can enter the laundry water, mainly through washing machines that has a pathogen killing effect in themselves by breaking the encapsulation and exposing potential pathogens to detergnets.

Perhaps the most significant difference between blackwater and greywater lies in the rate of decay of the pollutants in each. Blackwater consists largely of organic compounds that have already been exposed to one of nature's most efficient "treatment plants": the digestive tract of the human body. It is understandable that the by-products from this process do not rapidly further decompose when placed in water.

BOD curves

To get an idea of how oxidizable material affects the amount of oxygen in the water over time, BOD-curves should be constructed. Conventional BOD numbers are inadequate for assisting us in understanding how greywater and blackwater differ. Even though many different organic compounds are present in the various waste waters, the process of decomposition is usually described as a monomolecular or first-order reaction. Streeter& Phelps (Rennerfelt, 1958; Tsivoglou, 1958) use the following diffrerential equation:

$dy / dt = k' (La - y)$

where

La = total biochemical oxygen demand at the time $t = 0$

y = consumption of oxygen

k' = rate constant for the biochemical oxidation

The smaller k' is, the slower the decomposition. In the Swedish study [Tullander, Karlgren, Olsson] $k' = 0.1$ for blackwater in the graph below. After 5 days of decomposition, only 40% of the ultimate decomposition has been accomplished. [See Fig. 1] By contrast, the rate constant for greywater is $k' = 0.45$ and BOD5 for greywater has reached about 90% of Ultimate Oxygen Demand (UOD).

This rapid rate of decay (almost 65% per day) can be explained by the presence of organics which are, relative to the organics in blackwater, more readily available to micro-organisms.[Fig. 3]

Blackwater, by contrast, contains, in addition to feces, cellulose from toilet paper and nitrogen compounds (e.g., urea) from urine requiring oxygen for nitrification. All these processesh happen relatively slowly in a water environment and the nitrification typically does not even start until the carbon stage of the decomposition comes near its end.

Comparative Rates of Decomposition in Greywater and Blackwater.

(greywater = bath, dish and wash water; blackwater = water from flush toilets)

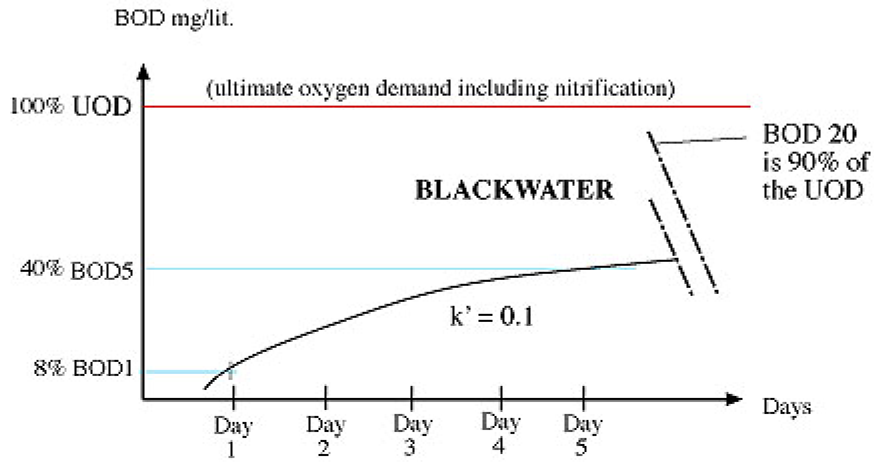


Fig. 1

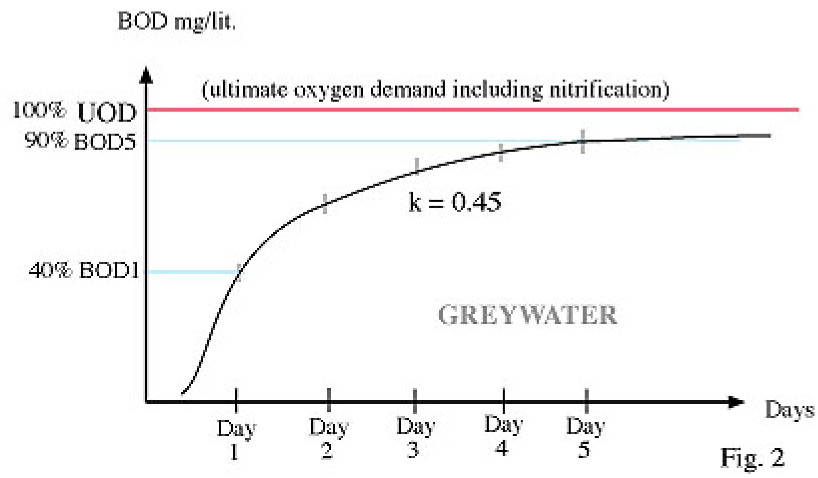
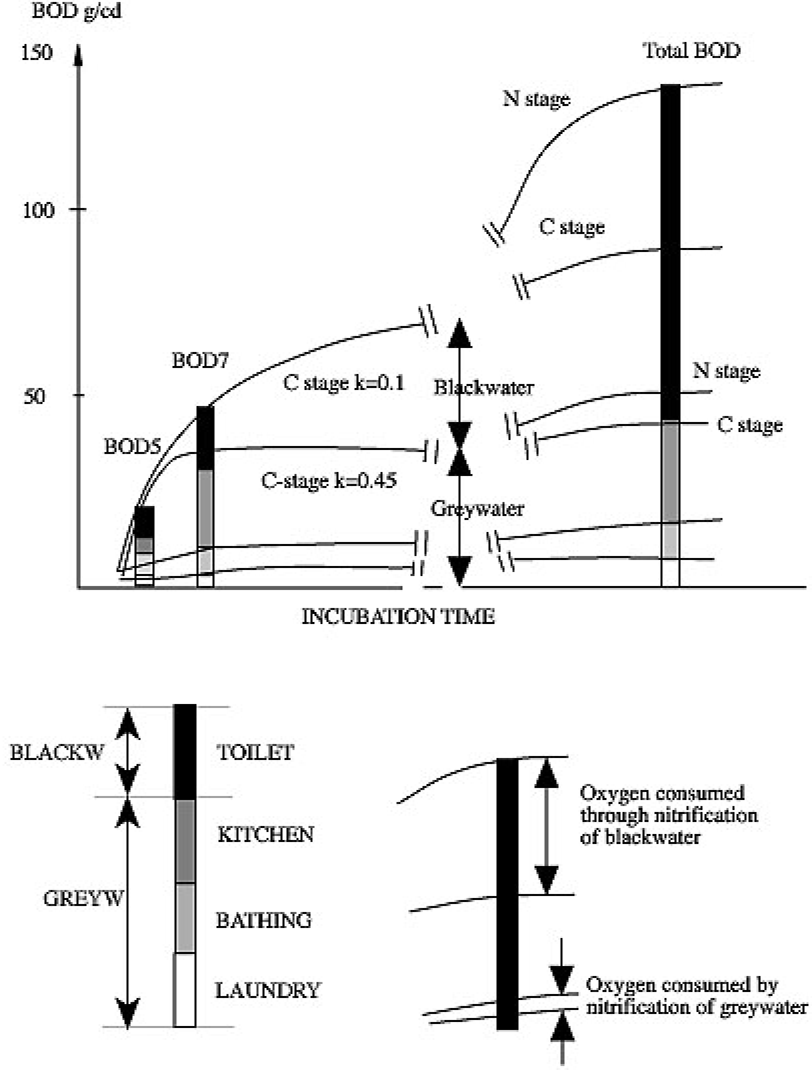


Fig. 2

Source: Olson E. et al. "Residential waste waters" - The Swedish National Institute of Building Research. 1967



From Residential Waste Water, Ahl, Karlgren, Olsson, Tullander. VATTEN 3 -67

Fig. 3

The significance of the differences in the rates of decomposition between grey- and blackwater are evident in terms of their relative impacts on ground water where treatment of blackwater and greywater is separated. Because of its rapid decomposition rate, greywater discharged into a stream or a lake will have a more immediate impact on the recipient body of water at the point of discharge than combined waste water. However, for the same reason, greywater will decompose faster in soils after infiltration and does not travel to pollute nearby drinkingwater nearly as much as do combined wastewater or blackwater discharge.

The safest and most effective way to prevent negative environmental impact from the by-products of our digestive systems is to keep them out of water altogether ---be it either surface or groundwater.

Confined, long-term (over-several-years), "natural" composting kills pathogens and transforms toilet wastes into odor-free fertilizers and a valuable soil conditioner. Confined, natural composting also keeps groundwater from being polluted by nitrates (sourced in urine to about 90%.)

Nitrite is one of the metabolic products when urine is oxidized through nitification.Nitrite is turned into nitrosamines in the stomach tract and is linked to cancer [non-Hodgkins lymphoma].

To maintain aerobic conditions, quick treatment is needed

Contrary to blackwater, greywater is not malodorous immediately after discharge. However, if it is collected in a tank, it will very quickly use up its oxygen (as explained on the previous pages) and will become anaerobic. Once it reaches the septic state, greywater forms sludge that either sinks or floats depending on its gas content and density. Septic greywater can be as foul-smelling as blackwaste and will also contain anaerobic bacteria, some of which can be human pathogens. Consequently, a key to successful greywater treatment lies in its immediate processing before it turns anaerobic.The simplest, most appropriate treatment technique consists of directly introducing freshly generated greywater into an active, live topsoil environment.

Figure 1 shows one time-tested greywater management approach which employs prefiltration to remove fibers and subsequent pressure infiltration using a piped distribution system that can be laid directly in the soil for plant irrigation. This treatment approach presupposes that the greywater does not contain any significant food waste and grease from kitchens. Figure 2 shows a system which relies either on gravity or batch dosing of raw greywater into a shallow soil environment see Nutricycle.

The Classic Swedish Study

The figures in Table 1 are from the Tullander, Ahl, and Olsen report published in Sweden in 1967 and still highly valued for its representation of the relative polluting chracteristics of the greywater and blackwater generated in a multi-storey apartment building in Stockholm whose plumbing separates grey and blackwater fixtures. The ultra-low flush toilet used in this investigation was a vacuum toilet using about one pint of water per flush. Sewage also contains pathogens capable of spreading disease. The great majority of these pathogenic organisms are derived from toilet waste which endanger the drinking water supply. (This issue will be addressed later with respect to greywater and the treatment method recommended to make it safe to recycle.) In the apartment building tested, there were several families with young children, accounting for a relatively high count of thermostable coliform 44° in the greywater, especially from the bathrooms and laundry. The risk of bacterial communication from the untreated greywater was estimated by the research team as low.

Table 1: Quantity and Relative Pollution in Greywater & Blackwater

Analysis	Greywater	Blackwater	Grey+Black	Greyw. %	Blackw. %
BOD5 g/p.d	25	20	45	56%	44 %
COD g/p.d	48	72	120	40 %	60 %
Total Phos.g/p.d	2.2	1.6	3.5	58 %	42 %
Kjeldahl N g/p.d	1.1	11	12.1	9 %	91 %
Total Residue g/p.d	77	53	130	58 %	41 %
Fixed Tot.Res. g/p.d	33	14	47	70 %	30 %
Volatile T.R. g/p.d	44	39	83	53 %	47 %
Nonfilterable g/p.d	18	20	48	38 %	62%
Fixed NonFilt.g/p.d	3	5	8	38 %	62 %
Volatile Nonfilterable g/p.d	15	25	40	38 %	62 %
Plate c 35[a]	83x10e9	62x10e9	145x10e9	57	43
Coli 35°	8.5x10e9	4.8x10e9	13x10e9	64	36
Coli 44°	1.7x10e9	3.8x10e9	6x10e9	31	69
Effluent flow (litres)	121.5	8.5	130	93	7
g/pd=gram/person.day(24h)		Ultra low-flush vacuum toilet			

The relatively high numbers of general bacteria are probably related to the high bacterial growth rate in the plumbing system itself. The human pathogens do not, as a rule, find growing conditions hospitable outside the human body.

This as well as many other studies demonstrate conclusively that about 90% of all water-borne pollutant nitrogen comes from flushtoilets--largely from urine.

Later data suggest that the amount of phosphates in detergents has, in recent years, been lowered significantly.

Data Compiled from other Studies

American Biochemist Dr. Margaret Findley has made a valuable, comprehsnive survey of research focusing on greywater/blackwater separation. She found five well-researched studies (1,2,3,4,5) and compiled data delineating their average quantity and quality as shown in Table 2. Though there is some variation, the patterns indicated lead us to propose alternative and, in our opinion, a more rational greywater management/treatment approach than that offered by current conventional technology.

Average Pollutants Loading (grams per person per day - g/p.d)		
Type	Greywater	Grey + Black combined
BOD5	34	71
SS	18	70
Tot. N	1.6	13.2
Tot P	3.1	4.6
Tot P*	0.5	1.9
* No Phosphorous detergent		

Table 2.

What is the goal of treatment?

Earlier water protection efforts focused almost entirely on sewage treatment to reduce primary, secondary and bacterial pollution. In the 1960s and '70s, central sewering was considered *the* answer to reducing water pollution. This naive belief disregarded the fact that huge amounts of sludge are generated by the central collection and treatment of sewage. Moreover, sewage sludge is unusable, containing as it does, not merely some fertilzing components but everything which our civilization chooses to "get rid of"--including toxic substances causing cancer, birth defects and a variety of health problems that we have only started to see manifested by pollution. Infectious disease problems, for example, have doubled in the last 40 years largely due to the disasterous results of pollution on our immune systems.

Although it is not yet government policy to **safely** retrieve the fertilizing value of now wasted organics from households, Clivus Multrum engineers, design its treatment processes with safe nutrient retrieval as its goal. In that context, experience tells us that greywater and blackwater must be treated and retrieved on-site before they get mixed and ruined by non-organics of unknown character. On-site composting of toilet and food wastes is more likely to accomplish the goal of retrieving household-generated organics without chemical contamination. Long-term composting kills human disease organisms, making its end-products safe for recycling. (A rare exception is the organism causing tetanus---an organism, incidentally, which can be found in any top soil.)

Conventional on-site treatment means septic tanks and leachfields. Since their function (except when they "back-up") is not detectable at ground level, they have been assumed to be "working". But the notion of "working" needs redefinition.The basic problem with conventional septic systems is that they introduce nutrients and microbes too deeply into the ground for any natural processes of decomposition and plant uptake to happen. In nature, almost all organic material is processed on or very near the surface by numerous macro- and micro-organisms. And plant uptake is the last--and-crucial--stage in the recycling of these nutrients.

Conventions for leaching facilities specify that beds or trenches be dug 24 " deep and filled with 6" of gravel, with 4" distribution pipes laid on the gravel and covered by an additional 2" of gravel followed by 12" of soil. The minimum distance between the bottom of the trench/field and groundwater or an impervious stratum must be no less than 4' according to the National Manual of Septic Tank Practices(14). The size of the leaching area is determined by the percolation rate. "The perc rate" is the standard test which measures the rate at which water escapes from a hole dug to the proposed depth of the seepage system. This rate must generally be faster than one inch per hour (expressed as "60 min/inch"). Since there is generally less plant uptake or other biological utilization of nutrients possible from these deep systems, inevitable long-term pollution is associated with them. When grey wastewater is infiltrated into shallow beds, however, the reduction of BOD and bacteria has been shown to be nearly complete (20), and the environmental impact will be from the chloride, nitrate and sulfate salts primarily associated with blackwater.

New, alternative greywater treatment/management technology which is now emerging (15,16,17,18,19) addresses the issue of direct groundwater contamination as well as the indirect pollution of lakes and rivers from failing septic systems. Many jurisdictions are adopting this new approach and have started to accept a variety of alternative technologies, some of which we will now describe.

Summary repeat - Key differences between Grey- and Blackwater:

- **Greywater decomposes much faster than does blackwater**
  - therefore, if injected near the surface of a bio-active soil, groundwater is better protected from organic pollution, since the treatment takes place rapidly in the soil and is practically finished two - three feet below the surface.
  - this is also the reason for the popular misconception that greywater is "stronger" than blackwater - the total effect of the 'grey pollution' is smaller but it shows up right away...
- **Greywater contains only one-tenth of the nitrogen contained in blackwater**
  - nitrogen (as nitrite and nitrate) is the most serious (cancer causing) and difficult-to-remove pollutant affecting drinking water. Therefore, logically, the removal of blackwater from septic tanks should give a septic-system owner a 90% "nitrogen credit"...
  - Furthermore ,the nitrogen found in greywater is around half organic nitrogen (i.e.,tied to organic matter) and can be filtered out and used by plants).