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SUSTAINABLE DEVELOPMENT OF WATER RESOURCES, WATER SUPPLY AND ENVIRONMENTAL SANITATION

Urban growth and wastewater agriculture: A study from Sri Lanka

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Rapid urbanization and increasing water consumption accelerate wastewater generation in cities in less developed regions. This has resulted in an intensification of the water pollution problem, which is now no longer, simply an issue for environmentalists to deal with, but which irrigation engineers are being called upon to tackle. Three cities in Sri Lanka were used to demonstrate the global situation. Data was collected using open-ended questionnaires covering a variety of issues associated with urbanization. Results show that the simple application of wastewater on surrounding agricultural lands has the potential to increase the cropping intensity. Out of three cities, Kurunegala paddy farmers use diluted wastewater for their irrigation. Better nutrient management in the field will help farmers to optimize fertilizer application. Health risk is the main negative force for wastewater agriculture. With risk reduction measures, wastewater recycling in agriculture becomes a potentially viable solution to waste disposal

Introduction

URBANIZATION is the driving force for modernization, economic growth, and development, but there is increasing concern about the effects of expanding cities, principally on human health, livelihoods, and the environment. With rural-urban migration, it has been estimated that by the year 2025, approximately 50 percent of the population will live in growing cities of less developed countries (LDCs). Large cities of 1 million or more with high population concentrations are increasingly associated with developing countries. There are an estimated 292 such “million plus cities” in LDCs. Mega cities with populations exceeding 10 million are also becoming more numerous and once more the predominance is in LDCs. Dhaka will add 9 million people to its population between 2000 and 2015 whereas New York in the same time frame will add only 800,000.

The implications of rapid urbanization on urban water supply and sanitation infrastructure are staggering. Water supply and waste disposal systems are unable to keep pace with development under resource poor environments, as is the case with LDCs. This results in much of the urban domestic (and industrial) wastewater being discharged untreated into urban waterways in spite of water quality guidelines and discharge standards being available in these countries. In cities with a predominance of urban and peri-urban agriculture (including agriculture on the outskirts of the city), the same watercourses serve irrigation and sometimes other household needs as well. Wastewater use in agriculture, in less developed country contexts, is clearly the result of poor urban sanitation. However the use of wastewater in agriculture has economic and environmental positives as well in a relative sense.

Sri Lanka has no mega cities, and the largest city is Colombo with a residential population of 642361 (2001 Census) and floating population of 500,000. Based on the 2001 census, (http://www.citypopulation.de/SriLanka.html), it is noted that major centres designated as cities and towns have a population of over 90000. The top 9 largest (Principal urban areas) cities have residential populations between 90000 and 650000. However, cities in Sri Lanka though relatively small are not exempt from this deteriorating water quality situation. Sri Lanka is blessed with high rainfall and perennial watercourses and it is unavoidable that cities are built close to water. This has resulted in intensification of the water pollution problem which is now no longer simply an issue for environmentalists to deal with, but which irrigation engineers are being called upon to tackle. Unfortunately insufficient information is available in Sri Lanka on the extents of wastewater irrigation. As part of a global survey on wastewater irrigation and agriculture practices, 3 cities in Sri Lanka were studied, namely Anuradhapura, Kandy and Kurunegala to quantify the extent and significance including the livelihoods dimension of wastewater irrigation and the range of conditions and factors that influence such use. This paper explores the wastewater irrigation situation in Sri Lanka with special attention to the driving forces behind this occurrence and the reactions of users, with a positive slant to such use, provided the risks associated are adequately addressed. Figure 1 shows the three selected cities.

Methodology

Extensive surveys using open-ended questionnaires were carried out in the three selected cities. The information sought related to volumes of wastewater generated, treatment and disposal practices, extents of agriculture (and aquaculture), its economic value and its significance as a livelihood strategy, and its health implications. Key stakeholder interviews were held to collect the additional information and secondary data was collected from published reports and existing water and irrigation databases etc. Transect walks were conducted through agriculture areas to observe the current irrigation practices. Volumes of wastewater generated in the cities were analyzed based on the population data and results were verified with the existing literature. City areas were defined by their municipal boundaries, so that the population figures indicated are specific to the municipal area.

Additionally, a substantial amount of data characterizing the cities in respect of water supply sanitation cover, water quality and land availability etc was obtained from the literature. The information was then analyzed towards developing a scenario where city wastewater is used in agriculture as an alternative to direct disposal as an option which may reduce the associated risks, and at the same time improve the livelihoods.

Definition of Wastewater

In this paper, it is assumed that urban wastewater may be a combination of some or all of the following (Van der Hoek, 2004).

1. Domestic effluent consisting of blackwater (excreta, urine and associated sludge) and grey water (kitchen and bathroom wastewater)
2. Water from commercial establishments and institutions, including hospitals
3. Industrial effluent
4. Storm water and other urban runoff.

Figure 1. Map showing three cities

Cities background

The three selected cities are in different climatic zones. Anuradhapura is in the dry zone, Kandy in the wet zone and Kurunegala in the intermediate zones. Rainfall varies between 1400mm to 2250mm (Table 1).

Anuradhapura shows the highest population growth rate (1.2%) and it is above the country population growth rate (1.1%). Highest population figures are in Kandy city and the population growth rate is 1.0%. Kandy city shows the highest poverty levels among the three cities.

Results and Discussion

The wastewater in the three cities comprised essentially of blackwater, greywater and storm water and urban runoff. All three cities had very little industrial effluent (eg industrial wastewater in Kurunegala city is less than 5%)

Water supply and waste water generation

Sri Lanka's total annual water resources (AWR) are 50 cubic kilometre and only 20% of this water is used in agriculture, industry and domestic purposes (total annual withdrawals). From this amount the agriculture sector utilizes nearly 96% and the domestic and industrial sector equally shares the remaining 4% (ADB 2002). Assuming a consumptive use of 20-40% for urban water use in general, we can say that on an average 70% of urban water returns as waste. 70% return of domestic water consumption is an internationally accepted figure for wastewater return flows. The calculation made using this figure is an estimate of potential available wastewater (for re-use) if the per capita consumption is as given. The authors re-iterate that some of the calculations in this paper are estimates made with the objective of arguing for alternatives to wastewater disposal in water bodies. Using these figures, an estimate of the annual total wastewater generation[1] in the country is 273 million cubic meters. A major part of this volume is diverted to the sea or surface water bodies.

Wastewater generation of a city is governed by many factors. According to city officials, as a rule of thumb, about 60% to 70% of the water supply to the city ends up in the canals as wastewater, though there can be variations in this

Table 1. Characteristics of the cities

City	Anurad-hapura	Kandy	Kurunegala
River Basin	Malwathu oya	Mahaw eli	Deduru oya
Population	56632	110049	28337
Average annual rate of growth	1.2%	1.0%	0.9%
City poverty index*	20	25	21.2
Rainfall mm	1400	2250	1690

*Percentage of people below income poverty line ie. Rs 1423 (2002).

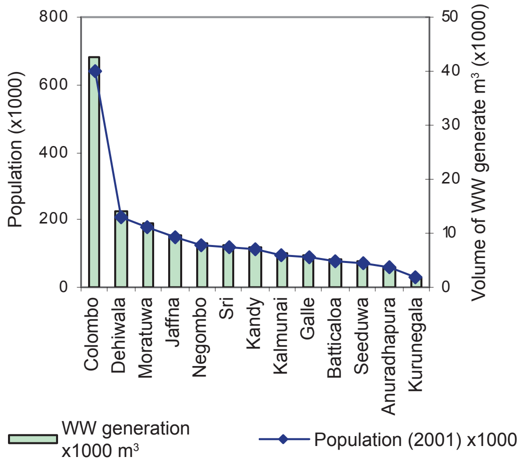

Figure 2. Population (2001) and wastewater generation in top 12 cities/urban areas in Sri Lanka

Table 2. Water supply and wastewater generation in the cities (2003)

City	Anurad-hapura	Kandy	Kurunegala
Actual LPCD*	290	335	260
Water supply % Pop Covered	90	95	90
Water supply% area covered	100	100	100
% unaccounted	30	32	30
Water** supply m^3/day	20440	25000	6863
Estimated wastewater generation m^3/day	14308	17500	4804

*Actual volume supplied divided by the population served (Liters Per Capita per Day).

**This value includes the actual supply by the water supply board and the amount of water estimated to be used by the house holds from other sources such as wells.

amount according to geographical location of cities, climate, and people's behaviour, level of industrialization etc.

Approximately 21.5% of the total population in Sri Lanka lives in urban areas, which cover 0.5% of the country's total land area showing in general a very high urban population density. For the 3 cities the range is 1753 to 4106 persons per km^2. 75% of the urban population is served with pipe borne water (by NWSDB). From a global perspective, Sri Lanka appears to be below the standards for South Asia which is 85% (Millennium Development Goals Country Report 2005). The National Water Supply and Drainage Board has set its own target for the supply of safe water to the entire population (urban and rural) at 85% for 2010 and 100% achievement by 2025. By 2001, almost 100% of the population in the Colombo metropolitan area had access to safe drinking water.

Based on a 70% of wastewater generation criteria, figure 2 shows the estimated wastewater[2] for the top 12 urban areas in Sri Lanka (population wise).

Based on the survey, the current situation in the three cities is shown in Table 2. There is 100% water supply coverage (by NWSDB) by area, for all three cities though the figure for coverage (access) by population is only 90 to 95%. Other than the government pipe-borne water supply people use their own sources such as ground water as well. Rather high water consumption figures are calculated values based on the water supplied to the city divided by the population (excluding floating) served, and not from household water consumption data. It therefore includes system losses as well which are in the 30%+ range. Except in the densely built-up city centre, most of the households discharge their grey water (washing and bathing) to their back yards where some of it is used to grow backyard trees and crops and eventually drains into groundwater. Wastewater collected in the sewers or canal systems may therefore be lower than the estimated figures indicated.

It is observed that most of the cities the daytime population is larger than the nighttime one as people enter in for various needs increasing the wastewater. As an example, 150,000 people enter Kurunegala city in a working day, about 50% of that number on a Saturday and about 20% of that on a Sunday. Wastewater generation from cities therefore shows not only a diurnal variation but also a variation between weekdays and weekends.

Wastewater disposal

Pipe-borne sewerage facilities in major urban areas in 2005 are shown in Table 3. Figures presented for 2006 and 2007 are projections. It is noteworthy that there is no proper pipe-borne sewerage facility in Kurunegala city. Kandy has only 5% coverage, and Anuradhapura has no sewer system (NWSDB 2003).

Where cities are located close to large rivers or the sea, cities usually dispose of wastewater into these sinks till such time as their carrying capacities are exceeded. This was the case for Colombo city a few years back (International Institute for Environment and Development 1992) when city wastewater (75%) was pumped into the Kelani river. Downstream this water was used for household and fishing purposes and some agriculture. Presently city wastewater is discharged (pumped) to the sea. This is done by the NWSDB and for the moment, they have two sea outfalls to the North & South of Colombo. For other cities this solution is not available and the closest water bodies are used as sinks. This is the case for developing cities like Kandy, Kurunegala, and Anuradhapura which are inland cities with rivers and streams flowing through or close to the city.

Anuradhapura city discharges wastewater to Malwathu Oya and Kandy city discharges in to Meda Ela and Hali Ela, which join the large perennial river named Mahaweli. Kurunegala city dumps its wastewater in to the Bue Ela, which flows through the city, and ends up in the perennial stream

Maguruoya. Cities can enjoy this privilege as long as the receiving water body is capable of buffering this inflow.

Currently urban wastewater management in the three cities centres around individual household disposal of wastewater and does not include collective systems except for storm-water drainage. Table 3 shows that only in 2 of the three cities studied, there is a proposed extension of the sewer network but even in these cases it does not exceed 11% which is very low.

Quality and composition of the wastewater

It may appear unreasonable to speak of the "quality" of wastewater, but when wastewater pollution affects irrigation water quality, the composition of the wastewater becomes critical. In the three cities, urban household wastewater is mostly the greywater from kitchens and bathing facilities. All three cities have onsite sanitation with only Kandy having a small pipeborne sewer network serving the city centre (Table 4) which means that the wastewater will have lower levels of faecal contamination and carry less risk. Furthermore the levels of helminth infections (helminths can be transmitted through crops grown with wastewater and affect farmers through direct contact), are likely to be low (given the routine de-worming campaigns in schools. Previous studies show low levels of infection, Peterson et al., 2003.)

Levels of industrialization are low in the three cities and they are mostly residential. The main risk appears in all cases to be from hospital wastewater which is being discharged untreated or partially treated. Most hospitals when newly constructed have treatment plants but many function poorly after an initial period of operation.

Figure 3 shows the break down for Kurunegala city (Ranaweera, 2005) which indicates the sources of wastewater and therefore the potential quality.

Table 3. Pipe borne sewerage facilities – Area coverage (NWSDB)

City	2005	2006	2007
Colombo Municipality (CMC)	80%	83%	85%
Dehiwala	27%	28%	30%
Kolonnawa	56%	58%	60%
Ratmalana & Moratuwa	20%	35%	50%
Ja-Ela, Ekala	25%	30%	40%
Kandy City Limit	**5%**	**9%**	**11%**
Nuwara-Eliya Town	5%	15%	23%
Galle	5%	10%	25%
Negombo	10%	25%	30%
Kotte	-	10%	20%
Jaffna	-	-	10%
Kurunegala	**-**	**-**	**10%**

Industrial contribution to contamination

Most of the industries in the three cities belong to the 'small' category (Osmani and Chandrasiri, 2002) and are scattered within the cities randomly. This pattern is common to older sections of cities in developing countries where industries are located within cities to benefit from urban infrastructure. New cities are planned with separate industrial zones. Industries in the Kurunegala city mostly drain their wastewater to the open drains without treatment. The industrial wastewater generated in Kurunegala city is mainly from the hospital and vehicle service stations.

Anuradhapura city has one large scale apparel industry and four medium scale industries (3 rice processing plants and a general hardware manufacturing industry). The industries within the city mostly drain wastewater to the open drains or Malwathu Oya which is close by. The rice processing plants in the city initially dispose their wastewater to an open pit or a sedimentation pit within their premises and then discharge to the watercourse in close proximity.

Table 4. Sanitation coverage percentages by households

City	Onsite sanitation*	Sewerage system
Anuradhapura	100%	-
Kandy	95%	5%
Kurunegala	98%	2%

*Onsite sanitation (septic tanks /dry pit latrines/ waterflush pit latrines).

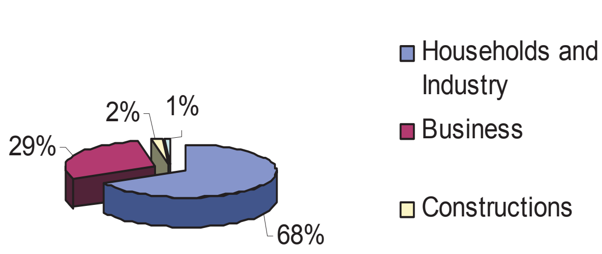

Figure 3. Wastewater composition in the Kurunegala city

The industries within the Kandy city (Bakeries and printing presses) mostly drain their wastewater to the open drains. As there are no large scale industries, there is low risk from heavy metal contamination in any of the cases.

Discharge standards for wastewater into inland waterways (CEA)[3] exist, but irrigation water quality guidelines are being developed (by CEA) in Sri Lanka. As an example, from a quality perspective, some parameters[4] of the Kurunegala wastewater exceed the tolerance limits for discharging water to inland water bodies (IEE report 2005) but, for agricultural water use, current discharge quality is well within the range (eg Salinity, pH, Biochemical Oxygen Demand, Chemical Oxygen Demand).

Can wastewater be used for agriculture in Sri Lanka?

Wastewater is widely used as an alternative to conventional irrigation water, even untreated, particularly when water for irrigation is in short supply (Van der Hoek, 2004). This is the case in parts of Pakistan, India, and China. Untreated wastewater is used for irrigation in over 80% of all Pakistani communities with a population of over 10,000 inhabitants (Ensink, et al., 2004). In treated form it is widely used in the middle-east, north african and Mediterranean countries and in parts of US and Australia to name a few countries. An emerging issue is the use of diluted wastewater in irrigation, resulting from wastewater pollution of original irrigation water sources (Raschid-Sally et al in press). In addition when it is used in urban and peri-urban agriculture, it supports livelihoods of urban poor and generates considerable value as food supplies to cities despite the health and environmental risks associated with this practice. Its common attraction is as a source of water but sometimes its nutrient value is also appreciated by farmers, as this leads to savings in fertilizer.

Disposal of wastewater in water bodies serving multiple purposes is usually strictly controlled and the standards to be achieved are stricter than for land disposal. From this perspective, it becomes interesting for developing countries to use this mode of disposal for urban wastewater particularly when industrial contamination is low. The paper indicates that except in the dense city centres, households still use septic tanks in these cities, so there is no extensive sewage collection system. The storm drainage system however is linked to the natural waterways in these cities, and sometimes collects sullage and even sewage through illegal disposal. Sullage is expected to be discharged in soakage pits and not to be connected to storm water drainage systems. If sullage can be collected separately, it can be used with fewer risks than sewage. Therefore, in poorer countries without resources for treatment, there is potential for such use in agriculture as a relatively safer method of wastewater disposal.

Of the 3 cities studied, Kurunegala typifies the use of wastewater in a rice system (Box 1). In Anuradhapura, the two examples of wastewater use typify the situation of (a) wastewater being used indirectly after dilution in the Malwathu Oya for vegetable cultivation and (b) Greywater from the military camp being used to cultivate vegetables. The latter case of direct use is similar to Pakistan (Van der hoek et al, 2002 and Ensink et al, 2004) where water scarcity is the driving factor. Kandy represents a wet zone agro-ecosystem with rainfed agriculture in the peri-urban areas. Both paddy and vegetables are grown but for these farmers agriculture is not the main source of income and they are not full-time farmers.

A possible scenario

If we assume that use of wastewater in agriculture (with risk reducing measures) is an environmentally sound means of wastewater disposal while at the same time increasing the economic productivity of the water (dual use for domestic purposes and then agricultural production), Table 5 shows total agricultural lands available near the cities and the current and potential cropping intensities (CI). It is noted that all the available lands were not cultivated and not harvested in both *maha* (wet) and *yala* (dry) seasons in year 2002 and 2003. Lands left without any production is very high in

Box 1. Wastewater agriculture in Kurunegala city

Kurunegala rice cultivation with wastewater is an example that typifies the potential impacts of urbanization on agriculture in Sri Lanka. The “Bue Ela” originating at the Wennaru Wewa, a tank used for multiple purposes including irrigation, and the “Waan Ela” originating in the paddy catchments upstream of the city, are two irrigation canals which now receive wastewater from city discharges. These canals within the city limits are about 8km long and traverse the city center collecting wastes from commercial and residential areas and some low-income residential development with inadequate sanitation. Additionally at some locations along the canals open defecation takes place, and leachates from unauthorized garbage dumps in the vicinity, add to the pollution levels. A high-risk pathogen source is also the Kurunegala hospital which discharges its waste (mostly) untreated into the canal system. These two canals meet together before the water is diverted to the irrigation canal at the Wilgoda anicut. Therefore, wastewater and irrigation water are mixed when it is supplied to the irrigated area.

Using this wastewater farmers cultivate around 100ha of paddy in both *yala* and *maha* (dry and wet) seasons. Farmers practice flood irrigation method to irrigate their lands. Interviews with farmers revealed that they were aware that the water contains some nutrient but it transpires that they are unable to benefit from it due to lack of understanding on nutrient management in waste water agriculture. Nevertheless, as there are no other source of surface water or ground water, farmers have to depend on the wastewater canal. Some farmers see wastewater as an opportunity if well managed, to benefit from the nutrients contained in it, but others complain about the health risks. Skin infections are likely to be the main problem though the risks have never been quantified. A current ongoing study (WASPA-Asia project) with EU funding coordinated by the International Water Management Institute (IWMI), Sri Lanka, is utilizing this case to explore the potential for recycling and resource recovery with accompanying measures for better sanitation and waste disposal to reduce risks.

yala season compare to the *maha* season. As an example, asweddumized[5] lands available near the Kurunegala city are 2002 ha but only 1971 ha are sown in *maha* and 1143 ha in *yala.* From the sown extent, only 1675 ha of paddy in *maha* and 1052 ha of paddy in *yala* reached harvest stage and the rest failed due to many reasons. The survey revealed, that inadequate rainfall and irrigation water were the main reasons among many other minor ones.

The difference between asweddumized extent and harvested extent shows the potential land availability near the cities. If there is a possibility to divert city wastewater onto those lands or diluted with available irrigation water to meet the total irrigation water requirement, more lands could be brought under cultivation and the cropping intensity increased. As an example, CI in Anuradhapura can be increased from 110% to 130%, Kandy from 110% to 200% and Kurunegala from 150% to 165%. Figure 4 shows the possible cultivable paddy extents (using their peak crop growth coefficient and 7 days irrigation interval) using current wastewater volumes.

However as can be seen in the Kandy case, a key constraint is of course availability of land. Though the potentially cultivable area is nearly 500 ha, there is only one third of that land actually available. This scenario was developed based on the estimated wastewater generation in the city. There are several other factors to be considered as well; notably hydrological factors such as seepage and infiltration, social factors such as attitudes of the people and authorities and very importantly the topography. The potential for re-use in the cases of the three cities is linked to the existence of an extensive separate collection system for sullage. In the event that the existing storm water collection system is to be used, then it has to be managed with this in mind.

Table 5. Lands availability and Cropping Intensity (CI) for agriculture around the three cities 2002/03 *maha* & 03 *yala* season

City	Anuradhapura	Kandy	Kurunegala
Asweddumized* extent (ha)	4390	175	2002
Maha sown Extent (ha)	4032	113	1971
Maha harvested Extent (ha)	3831	108	1675
Maha Unproductive lands(ha)	559	67	327
Yala sown Extent (ha)	880	81	1143
Yala harvested Extent (ha)	809	72	1052
Yala unproductive lands (ha)	3581	103	950
Current CI	110%	110%	150%
Possible CI after wastewater diversions	130%	200%	165%

*extent of lands ready for agriculture specially for paddy.

NB: Data relevant to the divisional secretariat where cities are located is used due to unavailability of exact extent around the cities.

Diversion of city wastewater into agricultural land will be easier in Anuradhapura and Kurunegala because of the flat terrain, while Kandy is in a hilly area making such a diversion difficult or economically unjustifiable. Health risk for the farmers and consumers and the market price for the crops also need to be considered. The advantage in water short areas like Anuradhapura is that such diversion to rain-fed areas will solve the frequent crop failures in such farming systems.

Conclusions

It appears from the 3 city case studies that wastewater use in agriculture in Sri Lanka would likely occur

1. Due to pollution of perennial water sources that were always used for irrigation, by urban wastewater,
2. Or under water scarcity conditions (as in the dry zone), where farmers would use it if it were the only available source of water.

Land application of wastewater for crop production is usually a more economical and environmentally acceptable solution to waste disposal provided the topography, and socio-cultural factors are suitable. In Sri Lanka the Kurunegala case indicates that cultural barriers are non-existent or could be easily overcome. Provided land is available in the vicinity of cities and with accompanying risk reduction measures therefore, wastewater recycling in agriculture becomes a potentially viable solution to waste disposal. The economics of such conversion however are strongly constrained by land availability.

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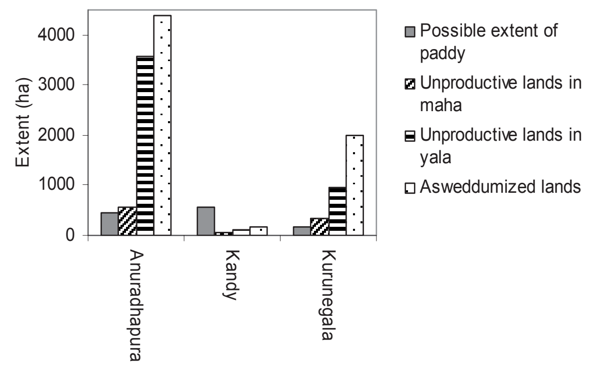

Figure 4. Possible cultivable extents (paddy) with generated wastewater in three cities

Notes

1. Wastewater generation = (AWR=50,000,000,000m^3) x 20% x 4% x 70%.
2. Population covered in urban areas 79%, average liters per capita per day 120 (from NWSDB) and assuming 70% of the domestic consumption ends up in wastewater canals.
3. Central Environmental Authority.
4. Eg Chemical Oxygen Demand, Sulfide, Fluoride.
5. Extent of lands ready for agriculture specially for paddy.

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