Integrated Approach to Sanitation Services

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Abstract

Little attention has been given to the treatment of the municipal sanitation services (MSS), namely drinking water service (DWS), wastewater and sewage service (WST), and solid waste service (MSW) as integrated systems. Historically these services evolved as separate technical and administrative domains. Standard engineering practice is to design, build and operate these systems as independent entities. A holistic vision of the services: their needs, impacts, and linkages provide an enhanced perspective where significant analytical and functional advantages are realized in treating the services as components of a single integrated sanitation system. The analytical advantage is that an integrated framework permits the parameters of the services to be modeled explicitly as inputs and outputs of the system. Thus, the dynamics of any component of the system can be propagated to assess likely impacts on other system components. This facilitates systems-based design and planning of municipal sanitation services. The functional advantages include possible economies of scale, leaner administration and higher economic, social, and environmental gains from system-wide strategies. Interventions combined in a single system can have greater impact than they might individually and implementing them together can be cheaper.

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1. Introduction and Research Gap

1. Little attention has been given to the treatment of the municipal sanitation services (MSS), namely drinking water service (DWS), wastewater and sewage service (WST), and solid waste service (MSW) as integrated systems. Historically these services evolved as separate technical and administrative domains[i,ii] Standard engineering practice is to design, build and operate these systems as independent entities. Furthermore, international development initiatives include only water supply and wastewater services in their definition of sanitation and also treat them as separate entities. Harremoes analyses the lifecycle of water flow through a society and concludes that integrating the materials flow of water supply and wastewater services is a promising alternative for achieving sustainable sanitation systems.[iii] Varis and Somlyody[iv] argue for urgent attention to urban sanitation needs and urban water infrastructure in developing countries.

2. While these studies note the need for both water supply and wastewater services, they fall short of proposing direct physical or institutional links between the two systems. Serageldin[v] similarly discusses the sequence of need, first for water supply then for wastewater removal and sewerage. Solid waste is not directly included, nor are physical or institutional links between water supply and wastewater services proposed. Gleick,[vi] Okun,[vii] Serageldin,[v] and others discuss strategies for addressing the shortage of sanitation services, primarily in developing countries. In many cases, they do not explicitly include solid waste management in the definition of sanitation.

3. The traditional approach treats each service as an independent entity. This explicitly ignores the institutional/administrative, physical, economic, environmental, and social interdependence between these services. This approach works in the industrialized, because the body of laws, regulations, administrative procedures, markets, supporting industries, and social processes that surround the MSS, implicitly accommodate the interdependencies between the services. In the developing such bodies of law, regulations, administrative procedures, markets, supporting industries, and social processes are relatively weak or absent. Thus, there is neither an implicit nor explicit accounting for the essential interdependencies between the services. In that case, untreated wastewater and sewage, and uncollected solid waste, are allowed to contaminate existing drinking water sources. This creates unsustainable negative feedbacks in the MSS supply system, which contributes to their eventual collapse.

2. Situation Analysis

4. In cities of developing countries, where there is often an absence or severe deficiency of all three services as shown Figure 1, the effects of treating the services as isolated entities compounds the impact of the deficiency. The environmental flows are of virgin materials withdrawn from their natural source, consumed then discarded as untreated waste back to the environment.

5. Drinking water is consumed with inadequate treatment, wastewater discharged without treatment, and municipal solid waste discarded in uncontrolled open dumps. The natural environment, particularly water bodies, serves as the source of drinking water and the sink for untreated wastewater, sewage, and solid waste. This practice exposes the resource to severe pollution, which threatens the health and well being of the population. Although these conditions may be confined to smaller, low-income, urban areas, squatter communities, and rural areas, the effects can transcend physical boundaries in the form of epidemics and regional environmental degradation.[viii]

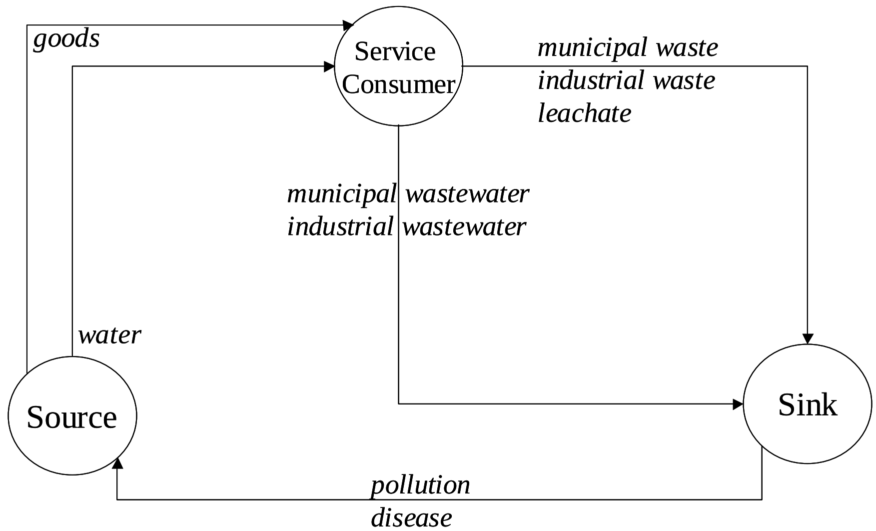


Figure 1: Systems Diagram: Lack of Sanitation Services

6. A development step up is the case where there is adequately treated drinking water as shown in Appendix 1: Figure 5. Health and well being may improve although those who promote sanitation to improve health will argue that drinking water and wastewater should be adjuncts of one another. Increasing potable domestic water supply without concomitant provisions for wastewater collection, treatment, and disposal will actually increase the regional burden of potable water treatment over the long term. This occurs because the availability of domestic water supply increases the production of wastewater as well as the physical, chemical, and biological loadings of those discharges.[ix] As a result, the macro environment actually bears elevated levels of pollution due to the improvement of drinking water service. The consequent deterioration in surface water quality ultimately increases the cost of future and downstream drinking water treatment. These increasing costs strain the already-stressed budget of the municipal water authority, ultimately leading to declines in the quality of drinking water provided and putting the service at risk of failure.

7. Drinking water treatment and supply services are well developed in selected, upper-income areas of developing countries, with wastewater and solid waste services lagging behind in varying degrees from some to no treatment or service at all.[x] An adequate wastewater service still falls short without adequate solid waste services that can treat its byproduct of biosolids and sludge as illustrated in Appendix 1: Figure 6. These wastes are often dumped along with other discards, which ultimately find their way to water sources via seepage or runoff, or as waste directly discarded into the canals and water bodies.

8. An adequate solid waste service also falls short without accompanying wastewater treatment for its leachate, which also can contaminate water bodies. This is illustrated in Appendix 1: Figure 7. A shortage of any of these services magnifies deficiencies in the other two services. For example, in many low-income communities, the lack of wastewater services results in bypass storm water drainage. These drains link discharge pipes from households to canals that collect storm water runoff. A shortage in solid waste services that leads to dumping and littering causes the clogging of these canals. Subsequently storm water and wastewater accumulate in cesspools.

These create unhealthy conditions for the populace from mosquitoes and other vector-borne diseases.

9. There are obvious material linkages between the sanitation services as shown in Figure 2. The services interact within a larger environmental system that functions as both source and sink. Ideally, the outputs as well as the rate of inputs (withdrawals) of the Municipal Sanitation System (MSS) should at the very least avoid degradation of the environment. Hence, a closed-loop system that protects the environment ensures the sustainability of the municipal sanitation system.

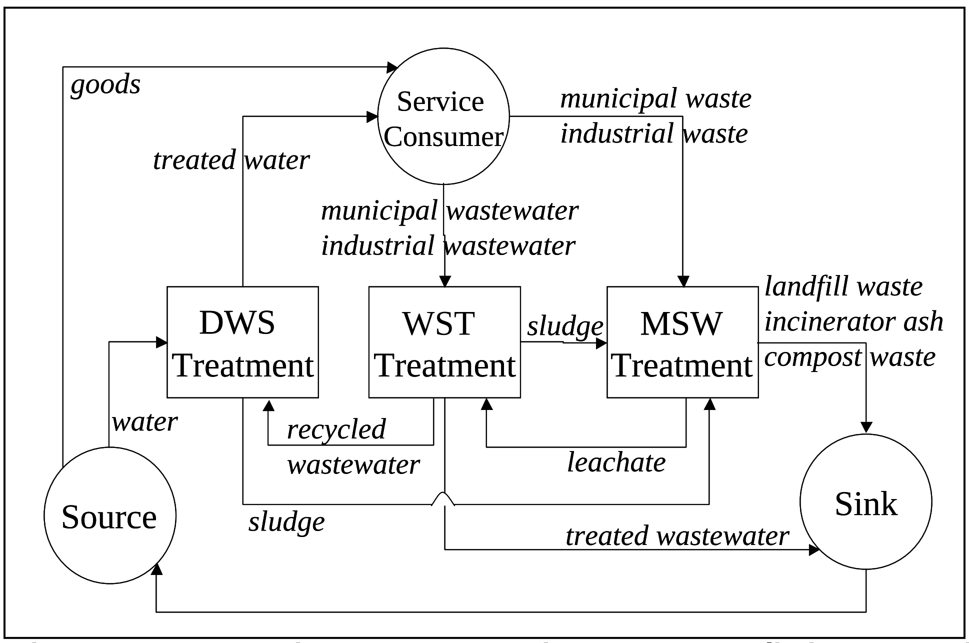


Figure 2: Systems Diagram: Integrated Systems: A Holistic Perspective

10. The input/output linkages between the services can be utilized in planning service capacity. Table 1 summarizes the shared input and output of MSS. Water is an output of DWS and after consumption becomes an input as wastewater to be treated by WST facilities. The volume of water consumption translates to the volume of wastewater for treatment and can be used as baseline for wastewater facility design.[ix]

11. The link to solid waste is observable as well.[xi] Sludge is an output of DWS and WST facilities and becomes an input for MSW treatment and disposal. Bio-solids or sludge are by-products of water and wastewater treatment and by definition is disposed of as solid waste.[ix] Even on-site wastewater treatment such as urban latrine pits and septic tanks must be periodically desludged and emptied, producing inputs for MSW treatment. Leachate is an output of MSW and becomes an input for WST. Solid waste

treatment produces wastewater in the form of leachate that need to be treated before discharging unto receiving waters.[ix]

Table 1: Material Input/ Output of MSS

Stream	System of Output	System of Input
Water	DWS	WST
Recycled Wastewater	WST	DWS
Sludge	DWS, WST	MSW
Leachate	MSW	WST

12. The system can be represented as a material balance model as shown in Figure 3. The procedure for solving material balance problem determines the stream variables. Thus, taking overall balances establishes unknown inputs and outputs within and outside the system. It should be noted however; that this part of the research will be explored in future studies.

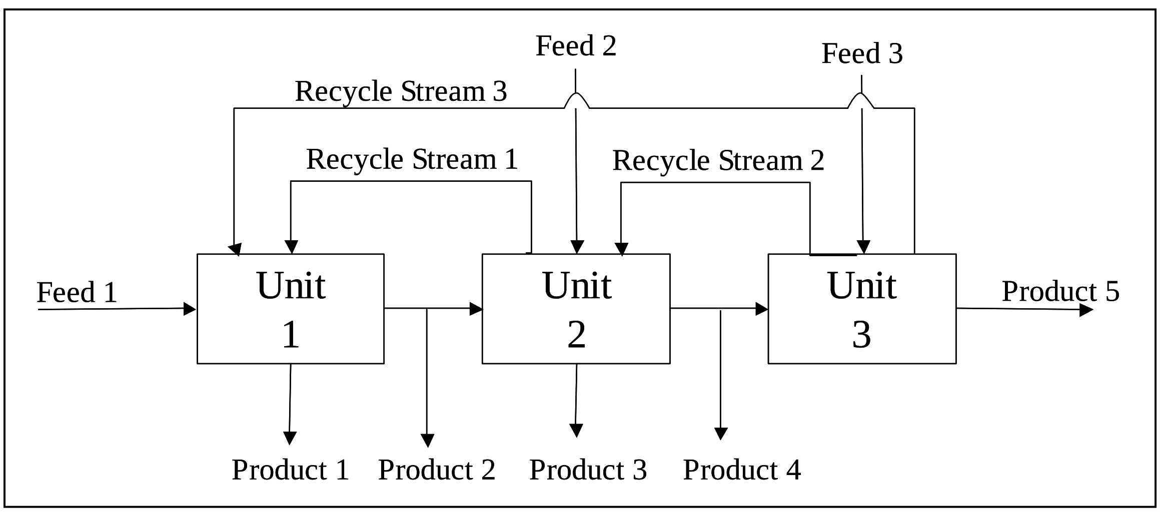


Figure 3: Material Balance Flow Chart of a Three-unit Process.

13. Other interdependencies such as institution linkages, financial/ economic, industrial, human/organizational and other links between the services were researched and detailed in Appendix 2, the details of which make the case for an integrated approach to a municipal sanitation system.

3. Alternative Approach: Integrated Municipal Sanitation System Paradigm

14. A holistic vision of the services: their needs, impacts, and linkages provide an enhanced perspective where significant analytical and functional advantages are realized in treating the services as components of a single integrated sanitation *system.*

The matrix model for MSS is illustrated in Figure 4. The model explores the potential functional integration of the three services. To some extent many examples of integrated services exist in some form or the other. The Delaware Solid Waste Authority (DSWA) has strategically located its largest landfill next to the public wastewater utility and connected its leachate pipes directly to the facility. In return for the service, DSWA agreed to dispose the sludge byproducts of the wastewater system. Truly integrated services are rare. One example is Metropolitan Toronto where the three services are the responsibility of one utility.

15. A helpful example of potential operational efficiency of an integrated MSS is the maintenance of pipes for water and sewer. Each service independently schedules maintenance and repairs for their own network of pipes. The procedure involves excavation of roads at separate times. Integrating the maintenance schedules for both water and sewer pipes could save effort, time, and cost. By timing the maintenance, only a one-time excavation of road is needed for both services instead of two separate occasions for each. Furthermore, personnel and crew can be shared as well as construction equipment.

16. The analytical advantage is that an integrated framework permits the parameters of the services to be modeled explicitly as inputs and outputs of the system. Thus, the dynamics of any component of the system can be propagated to assess likely impacts on other system components. This facilitates systems-based design and planning of municipal sanitation services. The functional advantages include possible economies of scale, leaner administration and higher economic, social, and environmental gains from system-wide strategies. Interventions combined in a single system can have greater impact than they might individually and implementing them together can be cheaper.

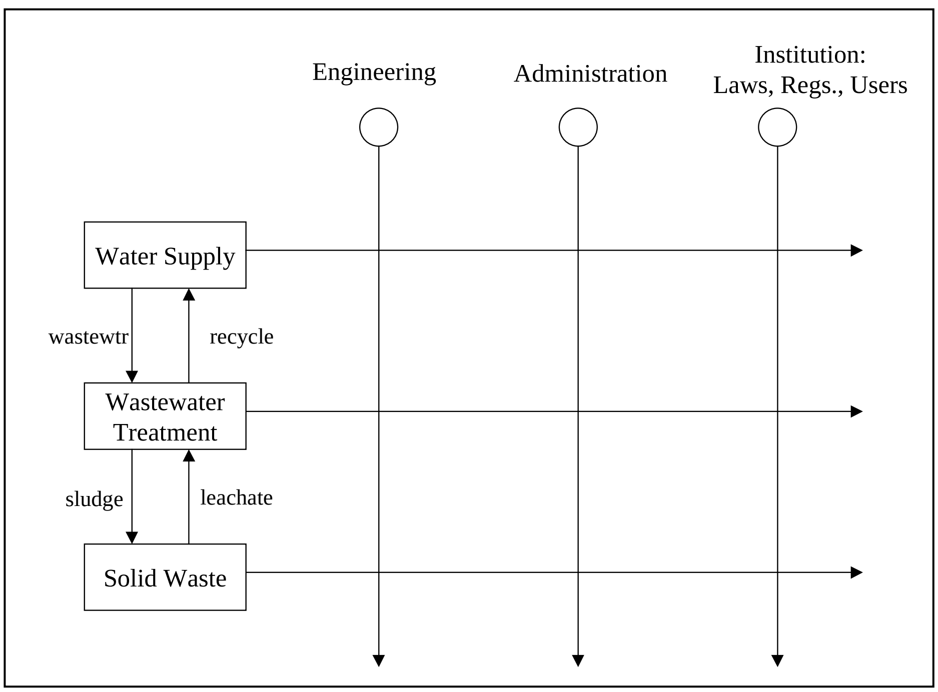


Figure 4: Matrix Model for the Municipal Sanitation System

References are detailed in Appendix 3.

Appendix 1: Figures 5, 6, and 7

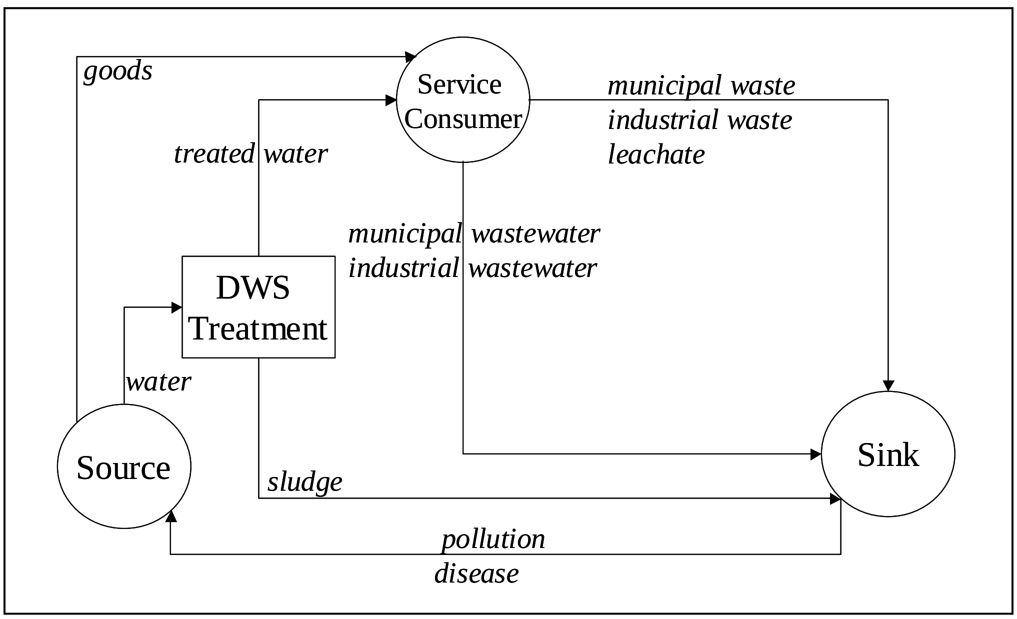


Figure 5: Systems Diagram: Availability of DWS Only

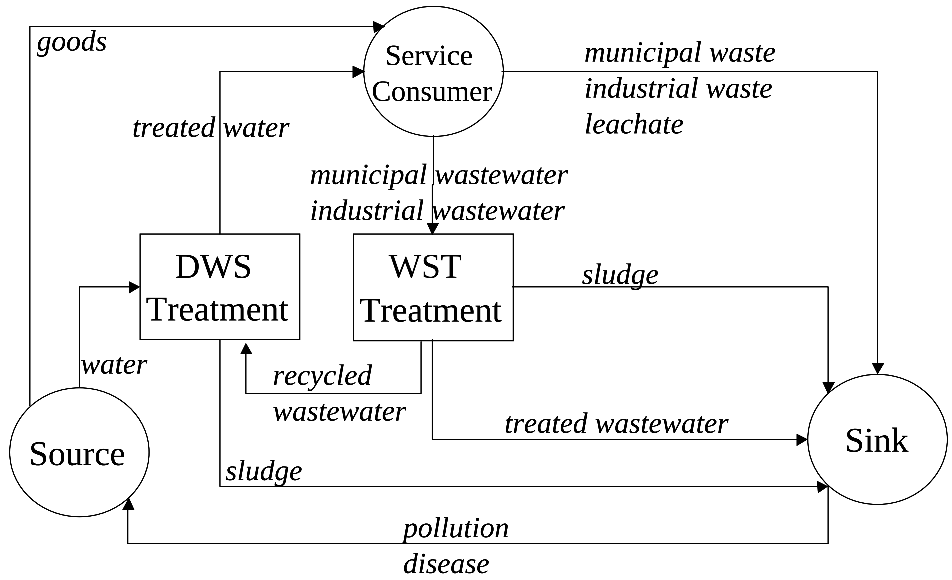


Figure 6. Systems Diagram: Availability of DWS and WST Only

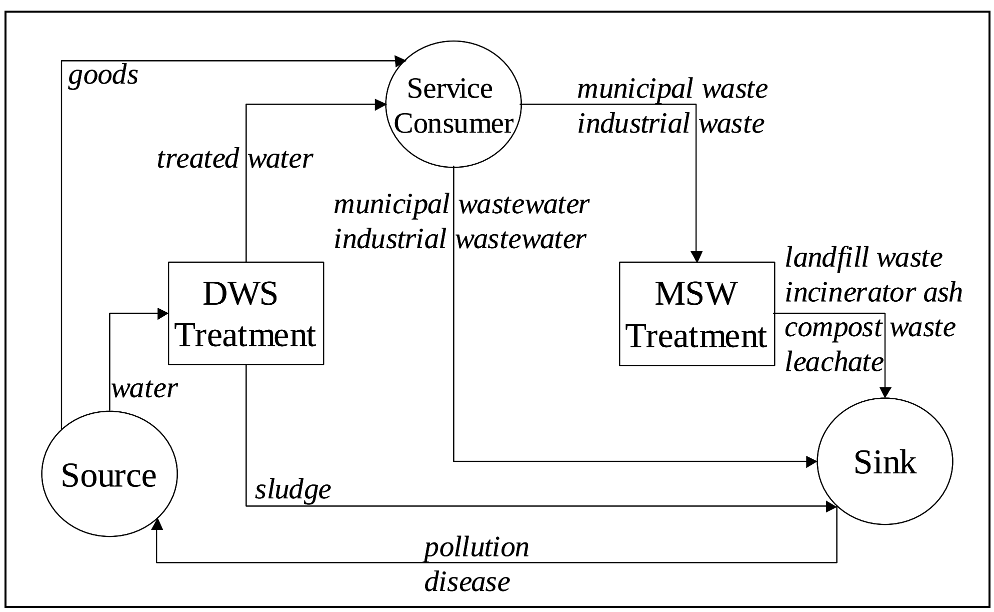


Figure 7. Systems Diagram: Availability of DWS and MSW Only

Appendix 2: Sanitation Service Interdependencies

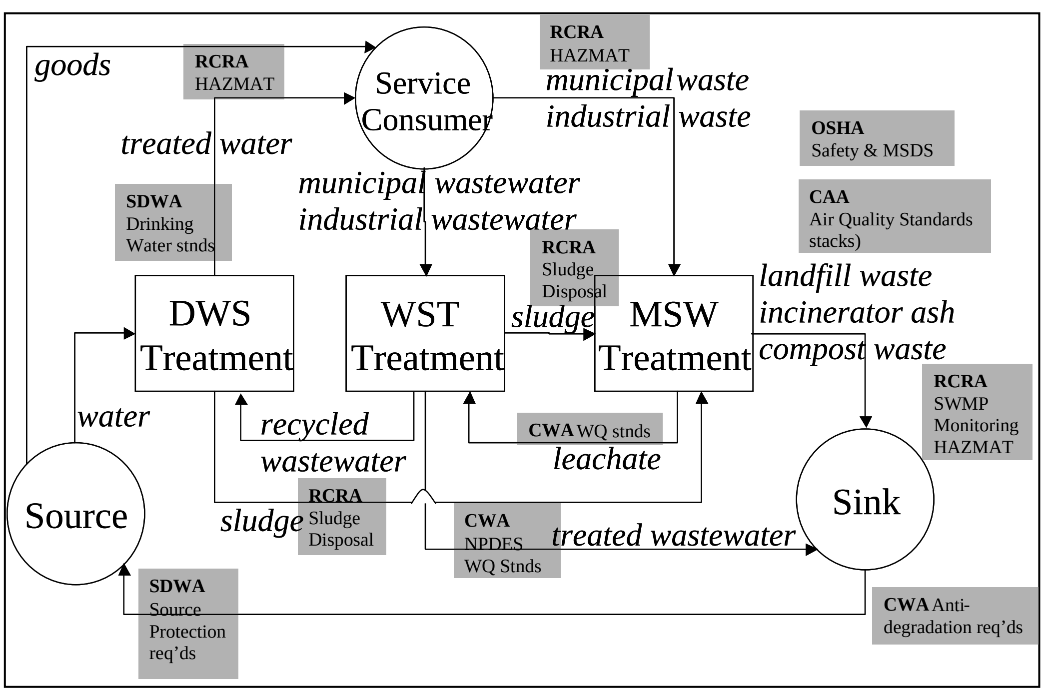
1.1 Institutional Linkages

In the United States, the Protection of the Environment law that governs the sanitation services are summarized as follows:

1. Air protection: Clean Air Act (CAA) for air quality standards by setting limits to how much pollutant can be in the air i.e. standards for emergency generator smoke stacks for incineration plants;[xii]
2. Water protection: The Safe Drinking Water Act (SDWA) sets standards to protect drinking water and its sources;[xiii] Clean Water Act (CWA) sets standards for surface water quality protection reducing direct pollutant discharges into waterways, financing municipal wastewater treatment facilities, and managing polluted runoff;[xiv]
3. Land protection: Resource Conservation and Recovery Act (RCRA) regulates and sets standards for managing solid and hazardous waste including discharge, storage, transport, and disposal requirements;[xv]
4. Human protection: Occupational, Safety, and Health Act (OSHA) for safety requirements.[xvi]

Figure 8 exhibits the laws and regulations that govern the system flows for the sanitation services. The CWA regulates WST output as well as MSW output to protect the water for DWS input. The SDWA source protection also protects the DWS input by regulating the locations and outputs of both WST and MSW. RCRA sludge disposal regulates sludge output of DWS and WST facilities by requiring appropriate treatment and disposal. The implementation and enforcement of these laws and regulations lie with administrative agents, namely the Environmental Protection Agency. The administrative processes governing compliance are similar for all three services.

Figure 8: Laws and Regulations for MSS Governing System Flows



The Clean Air for Europe (CAFE), the Drinking Water Directive, the Water Framework Directive, Urban Waste Water Treatment Directive, and the European Waste Directive basically cover the same standards and regulations for MSS in European countries. Many developing countries also have environmental legislation to govern their MSS. However, issues in enforcement and effectiveness, as well as compliance and applicability undermine MSS management and operations in these countries.[xvii] Agencies that deal with the three services are more separated and divided in developing countries.

1.2 Financial and Economic Interconnectedness

Most of the DWS, WST, and MSW service utilities in developing countries are public.[xviii] Infrastructure expenditures in developing countries have been funded directly from fiscal budgets. But several factors, such as macroeconomic instability and growing investment requirements have shown that public financing is volatile and in many countries rarely meets crucial infrastructure expenditure requirements in a timely and adequate manner.[xix] Hence the problem of service shortages is driven among other factors primarily by lack of funds.[xx]

Governments bear substantial financial burdens to sustain service deliveries; nevertheless service providers are chronically short of funds, preventing them from maintaining their infrastructure and from expanding it to reach the unserved.[xxi] Table 2 estimates the total magnitude of these subsidies, based on the volume of water used.[xxii]

For water, subsidy costs reach almost US$8 billion a year with the proportion of costs from subsidies as high as 94% in this sample of countries alone. For solid waste, World Bank estimates subsidies in developing countries to total about US$27 billion per year as shown in Table 3.[xxii] However, even with as much share of the pie, services are far from satisfactory.

Not only do these utilities have to wrestle for the limited public funds, but also compete for a part of consumer income in terms of user fees and delivery tariffs. Moreover, water utilities maintain that collection of revenues is seldom sufficient to cover their O&M, let alone capital costs. The impact of low tariffs on revenues is exacerbated by low collection rates. In some countries, only 15-30% of billings are actually collected.[xxii] As a result, water systems often fall into a low-level equilibrium trap in which utilities provide limited or low quality service because of insufficient resources and inadequate service lead to few resources being collected.

The obvious competition for the same pie is relevant in conceiving an integrated perspective of the services. Balanced investments between the services are crucial to maintain the environmental equilibrium. However, the relatively high political profile of the water sector makes it unduly favored in the past.[xxxiv] Though if perceived as an integrated package with wastewater and solid waste services can tip the favor for these previously neglected services.

Table 2: Water Subsidies on Delivery Tariffs in Selected Countries, 2000

	Water	*Subsidy*	*Domestic*	*Total*

Country	tariff ($US\$/m^3$)	Cost ($US\$/m^3$)	($US\$/m^3$)	(% of cost)	withdrawals (million m^3/ year)	subsidy (US$/ year)
Africa						
Burundi	0.17	0.66	0.49	74	36	18
Egypt	0.07	0.30	0.23	77	3,100	713
Lesotho	0.52	0.55	0.03	5	n.a.	n.a.
Malawi	0.20	0.36	0.16	44	95	15
Namibia	0.29	0.78	0.49	63	71	35
Nigeria	0.02	0.16	0.14	89	1,125	158
Senegal	0.66	0.99	0.33	33	68	22
Sierra Leone	0.30	0.54	0.24	44	26	6
Tanzania	0.20	0.30	0.10	33	101	10
Zimbabwe	0.10	0.30	0.20	67	171	34
Asia						
Bangladesh	0.09	0.20	0.11	55	1,704	187
Georgia	0.01	0.20	0.19	94	728	136
India	0.04	0.20	0.16	80	25,000	4,000
Indonesia	0.19	0.20	0.01	4	4,729	47
Iran	0.10	0.20	0.10	50	4,395	440
Nepal	0.09	0.20	0.11	55	246	27
Latin America	0.35	0.93	0.58	62	62	36
Barbados	0.20	0.30	0.10	33	124	12
Bolivia	0.25	0.30	0.05	17	5,233	262
Columbia	0.04	0.30	0.26	86	757	195
Costa Rica	0.07	0.30	0.23	77	2,545	585
Cuba	0.04	0.30	0.26	88	2,100	554
Ecuador	0.29	0.30	0.01	3	246	2
El Salvador	0.13	0.92	0.79	86	61	48
Honduras	0.35	0.96	0.61	64	65	39
Paraguay	0.20	0.30	0.11	35	1,800	198
Venezuela						

Source: Pagiola, Stefano; Martin-Hurtado, Roberto; Shyamsundar, Priya; Mani, Muthukumara; Silva, Patricia; Generating Public Sector Resources to Finance Sustainable Development, World Bank Technical Paper No. 538, World Bank Publications, Washington DC, 2002, Pp.20.

Table 3: Subsidies in Municipal Solid Waste Services, 1999

Region	Cost (billion US$)	MSW Subsidies Total (billion US$)	Per urban citizen ($)	Share of GDP (%)
Middle East and North Africa	1.6	0.6	3.8	0.10
Sub-Saharan Africa	0.9	0.3	1.2	0.10
Asia Pacific	44.3	15.5	12.6	0.70
Latin America and the	8.0	2.8	7.2	0.14
Caribbean	24.6	8.6	22.6	1.03
Eastern Europe and Central Asia				

Total	79.4	27.8	11.4	0.47

Source: Pagiola, Stefano; Martin-Hurtado, Roberto; Shyamsundar, Priya; Mani, Muthukumara; Silva, Patricia; Generating Public Sector Resources to Finance Sustainable Development, World Bank Technical Paper No. 538, World Bank Publications, Washington DC, 2002, Pp.20.

On the positive aspect, investment in public infrastructure projects, such as municipal sanitation services, exerts a significant growth impact on a regional economy driven by the resource utilization required for the financing, construction, operation, and maintenance of the projects.[xxiii] Economic development can be improved in a region through the economic multiplier benefits of infrastructure construction, motivation of water and water-related businesses, and labor productivity improvements through better health and quality of life. Increased supply of municipal sanitation services means that a greater amount of the largely inelastic but unmet demand for these services can be satisfied at an affordable price.[xxiii] Thus a larger segment of the population has access to the services.

More accessible municipal sanitation services, particularly potable water, can greatly improve the productivity of labor in a regional economy.[xxiii] For instance, an estimated 10 million person-years of efforts in fetching water, mostly by women and female children, in developing countries have been saved by the provision of safe and suitably located water supply.[xxiv]

Additionally, improved municipal sanitation service, can directly reduce the cost of healthcare associated with deficient sanitation services. Furthermore, the provision of sanitation infrastructure to an area can significantly increase property values in the region and attract secondary investments in residential and commercial development of the area.[xxiii] Thus, if evaluated on the basis of its potential contribution to regional economic development, investment in municipal sanitation infrastructure to meet unfulfilled demand and assure sustainable supply over the long term, must be considered a sound choice.

1.3 Industrial Association

The supply chain that supports the technology and service needs is similar for the MSS industries. This includes such services from construction to maintenance and repair of equipment and vehicles to hardware such as machinery, tools, and spare parts, to management support such as consultancy and software applications. Private engineering firms known to construct and develop facilities for the various sanitation services are currently being clustered as “environmental firms”.

A number of companies cater to more than one of the services. Hydromantis, Inc. offers environmental consulting and software solutions for both wastewater and water treatment. Hemmis, Environmental IT offers consultancy software for a range of environmental projects with applications for water, System for the Evaluation of Nutrient Transport to Water (SENTWA Model); for wastewater, Integrated Wastewater Treatment Plant and River Quality Modeling and Simulation (IWTPQMS**)**, and for solid waste, automation of Eurowaste services. ENTEC offers engineering design, construction, and installation for water, wastewater, and solid waste including expertise on environmental impact assessment, development planning, groundwater and surface modeling, and environmental health and safety.[xxv] These firms recognize and capitalize on the similarities and interrelationships between the services.

1.4 Human and Organizational Correspondence

Professionals and experts in MSS, primarily come from the engineering professions and function in the managerial and consultant positions. In developing countries, supervisory and blue-collar jobs in these industries come from low-income populations especially for WST and MSW where work is perceived to be unhealthy and unpleasant.[xxxi] The major issue in human and skills development is the disjoint of knowledge and skill of the interrelationship between the services that hinder the integration of the service into a single *system*. Few professionals are proficient in the management and operations of all three services.

The organizational models of the sanitation services are exceedingly similar, as with most utilities.[xxvi] The chief branch or section lies in the engineering departments that handle project management and operations and maintenance. The basic organizational chart is shown in

Figure 9.

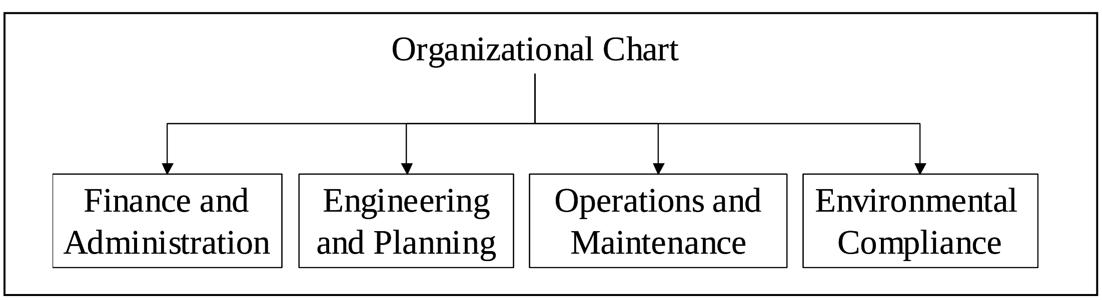


Figure 9. Organizational Chart for Sanitation Services

1.5 Social Connection

No single type of intervention has greater overall impact upon a country's public health especially the poor than do the provision of safe drinking water and the proper disposal of human excreta.[xxvii] Access to sanitation no matter how minor significantly affects the quality of life in communities.

The direct effects of improved water and sanitation services upon health are most clearly seen in the case of water-related diseases, which arise from the ingestion of pathogens in contaminated water or food and from insects or other vectors associated with water. For MSW services, the connection is more indirect. Crude solid waste management practices pollute air, water and land, fostering the proliferation of disease-carrying vectors that directly or indirectly affect public health, sanitation personnel, and those who scavenge the refuse.[xxviii]

The effects of poor sanitation to health are extensive. Poor sanitation and waste management infrastructure are still one of the principal causes of death and disability for the urban poor.[xxix] At any given time, an estimated 50% of the population in developing countries is suffering from water-related diseases.[xxx] The World Health Organization estimates that more than 5 million people die each year from diseases caused by unsafe drinking water and a lack of sanitation. Improved water and sanitation can reduce morbidity and mortality rates of some of the most serious of these diseases by 20% to 80%. [xxvii]

However, access to water and sanitation services for the poor tends to be assigned the lowest priority in public investment decisions due to the lack of political and economic power of this constituency.[xxxi] In many cities of developing countries, services are intermittent at best and nonexistent with abandoned infrastructure and institutions at worst. Increasingly, the urban poor in these cases must simply go without services. In the case of potable water, they are often left to the mercy of private vendors who charge prices that range from 4 to 100 times the rate that wealthy citizens pay for service from selectively distributed public supplies.[xxxii] This inequity in the distribution of services is aggravated by the fact that the noxious facilities that generate these services, especially for solid waste, are disproportionately sited in communities largely populated by socially and economically disadvantaged groups.[xxxiii,xviii]

Aesthetic life in these communities is degraded. Open dumps and open sewers not only threaten the immediate environment but also present unpleasant landscapes in affected areas. A vivid example is one of Manila's most striking topographical features, Smokey Mountain, where the mountain of trash defines the skyline and methane from rotting refuse burns in an acrid haze.[xxxiv]

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