ACCOUNTING FOR BIODIVERSITY AND ECOSYSTEM SERVICES FROM A MANAGEMENT ACCOUNTING PERSPECTIVE

Integrating biodiversity into business strategies at a wastewater treatment plant in Berlin

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Abstract

This case study deals with accounting for biodiversity and ecosystem services (BES) from the perspective of a wastewater treatment plant in Berlin. This industrial facility belongs to Berliner Wasser Betriebe (BWB), a public water services company owned at 49.9% by the consortium RWE-Veolia Water. This case study falls within Phase 2 of the *Orée*'s Working Group '*Integrating biodiversity into business strategy'* which aims to propose and test new methods in order to facilitate corporate decision-making regarding BES. Using the principles of Environmental Management Accounting (EMA), we seek to characterize the nature of the interactions between BWB's Wassmannsdorf wastewater treatment plant and BES. To that end, we assess whether costs or revenues may be associated with (a) identified input - output flows at Wassmannsdorf - with a particular emphasis on material flows of biodiversity and (b) ecosystem services influencing its operations and / or influenced by its activities. We show that, to satisfy contractual performance criteria, BWB management is currently mainly involved with (1) the management of ecosystem services within wastewater treatment plants, that of water purification (40% of total operating costs at Wassmannsdorf's plant) and sludge digestion (60% of total operating costs are related to sludge management, a significant share of which involves the digestion process) by micro-organisms, and (2) the quantity, content and delivery timing of wastewater entering WWTPs, which are influenced by various ecosystem (dis-)services within urban areas upstream. This has important implications in terms of the classification of 'environmental activities' for both EMA and systems of national accounts. To conclude, we discuss how BWB may systematically take biodiversity into account within its corporate strategies. This would require exploring complementary approaches towards promoting the diversity, variability and heterogeneity of living systems throughout the ecosystems with which the company interacts.

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Acknowledgements:

The authors gratefully acknowledge for their contributions to this publication:

- Patrick DURAND (Berlin Wasser Betriebe),
- Bernd HEINZMANN (Berlin Wasser Betriebe),
- Ghislaine HIERSO (Veolia Environnement, Orée),
- Fabienne MORGAUT (Orée),
- Mathieu TOLIAN (Veolia Environnement),
- Michel TROMMETTER (INRA),
- and Jacques WEBER (CIRAD).

1. Introducing Berliner Wasser Betriebe, a public water services company

In 1999, the Land of Berlin privatized 49.9 % of the shares of the public water services company Berliner Wasser Betriebe (BWB). The consortium RWE-Veolia Water obtained the contract for a period of 30 years: it owns the privatized shares and is remunerated through dividends. Through the terms of the contract, the consortium commits itself to improve the social and economic life of the Land by maintaining a cost effective service, having a responsible job policy, and keeping high environmental standards.

BWB's water service activities include drinking water production and distribution as well as wastewater collection and treatment. This case study is concerned with the latter. In Berlin, 224 million m³ of wastewater are collected and treated each year, for a population of 4 million people. The wastewater is collected through two types of sewer systems. In the city centre, a combined system collects domestic and industrial wastewater together with rainwater run-off whereas, in most of the suburbs, rainwater is collected separately. The collected effluents are treated by the six waste water treatment plants (WWTP).

Table 1: General data on the studied activity

Client	Land of Berlin
Operating Company	Berliner Wasser Betriebe (BWB)
Type of the contract	Shareholding and Management contract
Total population served	4 000.000
Volumes collected and treated	224 000 000 m³/year
Length of the combined system	1 908 km
Length of wastewater separate system	4 206 km
Length of rainwater separate system	3 218 km
Wastewater treatment sites	6 WWTPs with capacities varying from 40 000 m³/day to 240 000 m³/day
Total treatment capacity	656 200 m³/day ; 239 513 000 m³/year

The management of BWB's wastewater treatment activities takes place at different levels:

A. An executive board, involving the Land and the consortium, oversees the strategic orientations, including quality and security standards[3], fares and investments.

B. According to these orientations, BWB management sets the budget and objectives for each plant. A centralized control structure supervises the allocation of the collected urban effluents between the six wastewater treatment plants (WWTP) of Berlin.

C. At the level of the plants, the teams deal with day-to-day operations, in cooperation

[3] For wastewater treatment, the quality standards concern the characteristics of the treated wastewater at the outlet of the plant. The security standards concern the capacity of treatment in case of heavy rainfall. According to German standards, the plants need to maintain a capacity of at least two times the capacity needs under dry weather conditions.

with the centralized control structure, so as to comply with standards in a cost-efficient way.

2. Aims and methods of the case study

Biodiversity refers to the dynamics of interactions between organisms in changing environments. This case study deals with accounting for biodiversity and ecosystem services (BES) from the perspective of a wastewater treatment plant in Berlin, BWB's Wassmannsdorf's facility. It falls within Phase 2 of the *Orée*'s Working Group '*Integrating biodiversity into business strategies*', which aims to propose and test new methods in order to facilitate corporate decision-making regarding BES. Using the principles of Environmental Management Accounting (EMA), we seek to (1) characterize the interactions between Wassmannsdorf wastewater treatment plant and BES and (2) discuss what could be done by BWB to fully integrate biodiversity into its corporate strategies.

EMA is broadly defined to be the identification, collection, analysis and use of two types of information for internal decision making (UNDSD 2001; Savage and Jasch, 2005), namely (a) monetary information on environment-related costs, earnings and savings and (b) physical information on the use, flows and destinies of energy, water and materials (including waste). EMA may be particularly valuable for internal management initiatives with a specific environmental focus, such as environmental management systems, product or service eco-design, cleaner production and supply chain management.

Using methods proposed by Houdet et al. (2009a), we have attempted to assess whether costs and revenues can be associated with (a) identified input - output flows at Wassmannsdorf - with a particular emphasis on material flows of biodiversity (section 5) - and (b) ecosystem services influencing its operations and influenced by its activities (section 6). To that end, we needed to understand the wastewater treatment process (section 3), budget allocation and cost management (section 4) at Wassmannsdorf's plant. We discuss the strategic implications of our main findings in section 7.

3. The wastewater treatment process at Wassmannsdorf's plant

Wassmannsdorf's plant (see aerial picture below) is one of the six WWTPs operated by BWB. This plant has a cleaning capacity of 230 000 m^3/day and treats together with Ruhleben's plant (West Berlin) more than half of the collected effluents in Berlin.

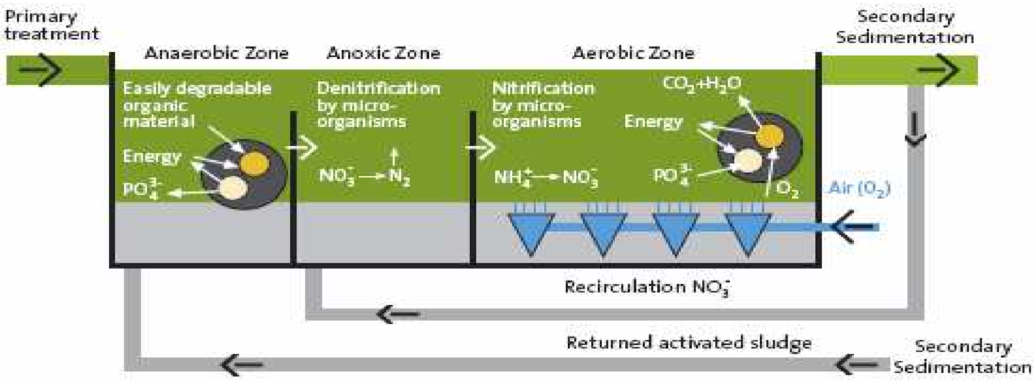

Figure 1: The wastewater treatment process at Wassmanns-dorf's plant.

The wastewater treatment process consists of the following steps (Figure 1):

A. Pre-treatment gets rid of solid wastes (pieces of wood, leaves, cans, plastic objects, gravels, sands…) and primary decantation aims to collect the 'primary sludge' as well as grease floating on the surface.

B. During biological treatment, organic compounds, nitrogen compounds and phosphorus are eliminated thanks to the development of bacteria within the tanks. The water circulates through zones with different oxygenation conditions:

o The reduction of the availability of oxygen modifies the metabolism of bacteria in order to achieve phosphorus removal and nitrification / de-nitrification (ammonium oxidized via nitrite to nitrate and then reduced to molecular oxygen and nitrogen gas);

o In the aerobic zone, fine-bubbled surface ventilation circulates oxygen into the wastewater-sludge mixture in order to maximize the activity of micro-organisms. In addition, a precipitating agent (iron sulphate) is sometimes used to enhance the rate of phosphorus removal, especially during winter because bacterial activity declines as water temperature decreases.

After biological treatment, the sludge is separated from treated water by decantation. Treated water is discharged into aquatic ecosystems. A part of the sludge is returned to the head of the treatment tank while the rest is removed. The ratio sludge returned/removed allows the plant managers to keep in balance the ratio between the 'food supply' (organic compounds) and the biomass of micro-organisms within the treatment tanks. This is also used to monitor 'sludge age' (i.e. the average time spent by bacteria in the system) as well as the maturity and the diversity of the metabolic chain.

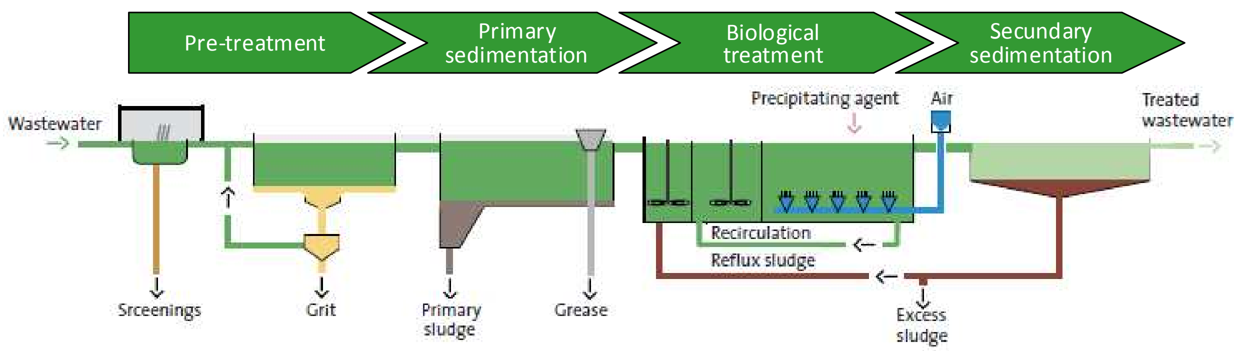

Figure 2: Activated sludge with nitrification / de-nitrification and phosphorus removal

C. For instance, 'older' sludge age generates higher conversion rates of ammonia to nitrate, though beyond a certain maturity threshold, operating risks materialize due to the proliferation of filamentous organisms and the emergence of undesired species (e.g. worms).

The treatment of wastewater produces large volumes of sludge, a mixture of water, micro-organisms, organic matter and diverse pollutants removed from wastewater. Sludge management represents a very significant part of wastewater treatment activity. Sludge has to be stored, treated, dewatered, eventually dried, and finally disposed of (Figure 3). Sludge treatment, also known as 'digestion', is a biological process which reduces the amount of organic matter and micro-organisms within solid outputs. At Wassmannsdorf, the digestion process, operated in anaerobic conditions, generates large volumes of biogas used to produce electricity which is sold to a public electricity utility. Digested sludge is mechanically dewatered in centrifuges, with flocculants helping to further remove liquids. In Wassmannsdorf, due to mining activities upstream, wastewater treatment sludge contains levels of heavy metals which do not allow spreading it on farms and landfills. Some of the dewatered sludge is carried to the incinerator of Ruhleben's WWTP. Some is transported to a thermal power plant where it is co-incinerated.

The remaining sludge is carried to rotary dryers so as to produce pelletized granulates used as fuel by a cement factory.

4. Budget allocation and cost management at Wassmannsdorf's plant

This section aims to present a quick overview of cost management at BWB's Wassmannsdorf's wastewater treatment plant, revenues being collected directly by BWB's headquarters.

BWB services[4] are charged all together via the invoice paid by water users. This invoice includes a fare, calculated in Euros per m^3 of water used, which covers wastewater collection and treatment costs: this provides around 75% of BWB's total income. An additional fare, paid by owners of impermeable areas (local public authorities and private owners) and calculated in Euros per impermeable m^2 (roofs, asphalt surfaces), covers the costs for rainwater run-off collection and treatment (25% of BWB's total income).

In this context, the challenge for BWB is to two-pronged: ensuring the stability of the price of drinking water (due to stakeholders' pressures) while finding the financial resources for investment purposes. Investments are driven by statutory standards and client's expectations in terms of security and quality.

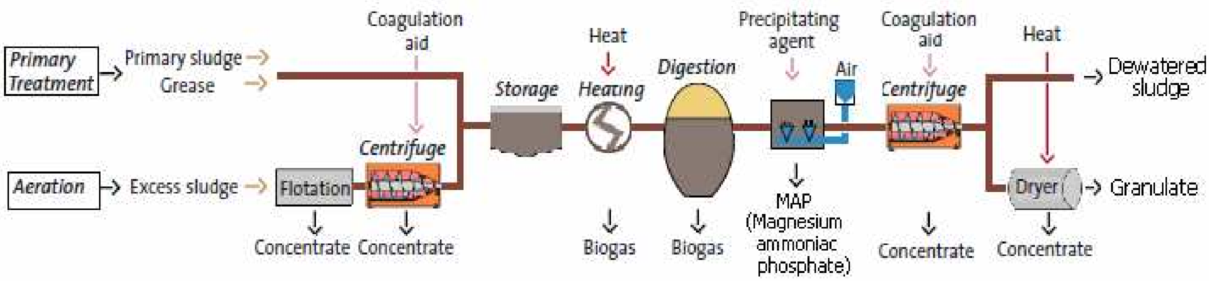

Figure 3: Sludge treatment process at Wassmannsdorf's plant

[4] As aforementioned, BWB's services include drinking water production-distribution and wastewater collection-treatment.

Once the plant is designed, the most important investments arise from the necessity to maintain the water treatment capacities at a secure level, in other words at a level which allows to face peak rain events. Other investments can result from the evolution of quality expectations or equipments renewal needs. According to forecasted revenues and costs, annual budgets and objectives (in terms of quality and cost-efficiency of wastewater treatment) are calculated and assigned to each plant.

At BWB, cost control efficiency for wastewater treatment plants is usually expressed in terms of the money spent by cubic meter of treated water (€/m^3). This allows management to compare costs using volume data correlated with the revenue of the activity: the volume of wastewater treated is essentially contingent on the volume of drinking water consumed (rainwater represents only 10% of the volumes treated annually).

Furthermore, Table 1 presents the main cost categories at Wassmannsdorf's wastewater treatment plant. To satisfy discharge standards (Table 2), 53% of total operating costs relate to human resources. More specifically, 70% of the latter concern sludge treatment, an industrial process involving electro-mechanical equipments (water treatment is highly automated). In addition, to keep sludge driers working continuously, teams affected to this part of the process work day and night in three 8-hours shifts.

Energy purchase represents more than 25% of the expenses of the plant: it is strongly connected to the volume of treated wastewater and its pollution load. Sludge rotary driers consume large amounts of natural gas. Aeration for activated-sludge treatment is the most electricity consuming task. The rest of the electricity consumption is principally due to water and sludge pumping at each step of their treatment process.

Table 2: Cost categories, expressed in percentages, of Wassmannsdorf's wastewater treatment plant

Share of the total operating costs of the plant	
Energy purchase	27%
Salts & polymers purchase	2%
Human resources	53%
Other costs	18%

While salts and polymers purchase do not represent significant purchases, other costs include subcontracting (co-generator maintenance, payment for dewatered sludge and granulates disposal, green areas management), small equipment purchases (measuring instruments, pipes, containers), interests and amortizations of the investments on turning equipment, and provisions spreading predictable maintenance costs over the years.

Table 3: Flows of pollutants (Wassmannsdorf Wastewater Treatment Plant, data for the year 2007 provided by BWB management)

	Effluent	**Discharge**	***Standards required***
5-day Biological Oxygen Demand (BOD_5)	424.0 mg/l	3.8 mg/l	*10 mg/l*
Chemical Oxygen Demand (COD)	984.5 mg/l	49.4 mg/l	*65 mg/l*
Suspended Solids (SS)	549.9 mg/l	7.1 mg/l	*20 mg/l*
Ammoniacal-nitrogen (NH4-N)	58.9 mg/l	0.3 mg/l	*5.0 mg/l*
Total Phosphorus (PT)	11.7 mg/l	0.4 mg/l	*0.5 mg/l*

5. Identifying material flows of biodiversity

This first phase of our work deals with the identification of material flows at Wassmannsdorf's wastewater treatment, which falls within a standard approach to Environmental Management Accounting (i.e. identifying environmental flows so as to reduce their associated impacts).

Figure 4 presents material and energy flows at Wassmannsdorf's plant. Though various identified inputs and outputs have impacts on ecosystems (e.g. CO_2 emissions, wastes) throughout their life-cycles (e.g. purchased inputs imported from elsewhere), we chose to focus our analysis on material flows of biodiversity (MFB; for definitions see Houdet et al., 2009). These are presented in Table 4 on the next page. Various materials derived from biodiversity play a role at Wassmannsdorf, highlighting its dependence on them. In addition, outputs derived from biodiversity influence the ecosystems which receive them (e.g. water discharges).

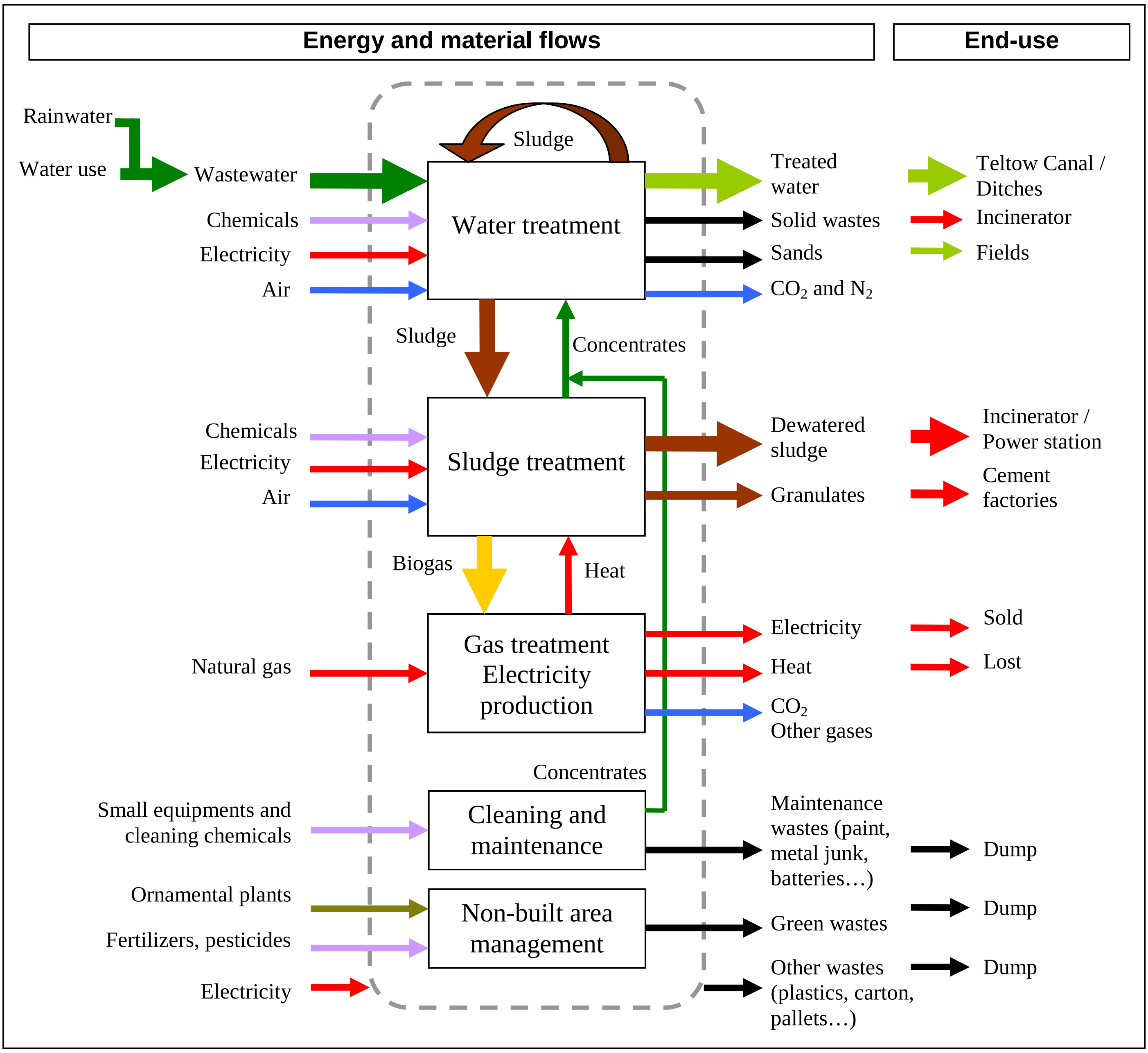

Figure 4 : Energy and material flowchart at Wassmannsdorf's plant

Table 4: Associating material flows of biodiversity with costs and revenues

Material Flows	Units	Associated monetary transactions
Material flows directly linked to a monetary transaction		
Sold biodiversity outputs		
Materials derived from transformed biological material		
Electricity produced from biogas	KWh sold to an electricity-utility company	Revenue registered in revenue accounts (only income source at the WWTP level, representing 30% of energy expenses)
Purchased biodiversity inputs		
Materials derived from transformed biological material		
Chemicals	Kilogram or ton as specified in the purchase documents	Purchase cost registered in expense accounts: 2% of the operating costs
Natural gas	m^3 as specified in the purchase documents	Purchase cost registered in expense accounts: 11% of the operating costs
Part of the electricity purchased (fossil fuels)	KWh, apply a percentage to the total electricity purchase according to the energy mix of the provider	Purchase cost registered in expense accounts. Total energy purchases represent 16% of the operating costs
Untransformed biological material		
Part of the electricity purchased (biomass, biogas)	KWh, apply a percentage to the total electricity purchase according to the energy mix of the provider	Purchase cost registered in expense accounts. Total energy purchases represent 16% of the operating costs
'Paid' Biodiversity outputs		
Sludge subproducts (dewatered sludge, granulates) and organic wastes	Kilograms or tons as specified in the delivery documents	Costs related to the disposal of sludge subproducts and organic wastes registered in expense accounts
Material flows not directly associated to a monetary transaction		
Free biodiversity input		
Micro-organisms in wastewater	Not recorded at the present time. Number of individuals or grams of biomass measured on samples and extrapolated to the total volume of wastewater.	No direct cost or revenue. However, the activity of micro-organisms is critical to wastewater treatment. Ideal conditions for their development must be maintained. We may speak of 'engineer species' which help achieve specific organizational outcomes.
"Non-chosen" biodiversity input		
Organic matter in wastewater	Kilograms, assessed thanks to Chemical oxygen demand (COD), measured per litter and multiplied by the total volumes treated.	Costs linked to the biological treatment (in particular electricity needs for aerobic zone ventilation).
Biodiversity residues		
Micro-organisms in treated water	Not recorded at the present time. Number of individuals or grams of biomass measured on samples and extrapolated to the total volume of wastewater.	No related cost or revenue
Organic matter in treated water	Kilograms, assessed thanks to Chemical oxygen demand (COD), measured per litter and multiplied by the total volumes treated.	No related cost or revenue; however, BWB must satisfy water quality criteria for discharges (Table 3): the management treatment costs aims to satisfy them.
Gas emissions resulting from water treatment	m^3 of gas emitted (biogenic emissions[5] are not measured)	No related cost or revenue
Gas emissions resulting from biogas and from natural gas combustion	Measured m^3 and compounds of the gas emitted	No related cost or revenue

Given the small amounts of purchased biodiversity inputs, the uncertainty regarding their origin (life-cycles / modes of production and associated impacts) and, especially, the nature of the activity, we chose to focus our analysis on the micro-organisms in the treatment of wastewater and the digestion of

[5] Biogenic emissions arise from the biological degradation of the carbon captured in organic matter. Because of their biological origin, they are not anthropogenic emissions (ADEME 2007).

sludge[6]. Through there is no monetary transaction directly linked to them, organizational outcomes chiefly depend on their activity. As previously shown, BWB's contractual agreement is based on the achievement of certain water quality criteria (Table 3; i.e. thresholds for pollutants in discharges). By managing the appropriate conditions which sustain, increase or reduce the activity of various functional groups of micro-organisms at each stage of the industrial processes involved, BWB aims to treat wastewater and digest sludge efficiently.

6. Understanding interactions with ecosystem services

Because an approach focused exclusively on material and energy flows fails to fully assess the interactions between business and biodiversity (Houdet 2008), the second phase of our work aims to provide a complementary understanding of the interactions between Wassmannsdorf's WWTP and the ecosystems within which it operates. From this perspective, we have identified, in a rough and ready way, the nature of its interactions with ecosystem services. We distinguish various categories of interactions between Wassmannsdorf's plant and ecosystem services (Figure 5).

- ES1 - Ecosystem (dis-)services directly and indirectly influencing BWB's activity:

A. Ecosystem (dis-)services which influence wastewater collection and treatment;

B. Ecosystem (dis-)services which are managed on-site at Wassmannsdorf's WWTP.

- ES2 - Ecosystem (dis-)services influenced by BWB's activity:

A. Ecosystem (dis-)services influenced by BWB wastewater collection and treatment infrastructures ;

B. Ecosystem (dis-)services influenced by the outputs of Wassmannsdorf's plant.

These four categories are successively discussed as follows:

ES1-A refers to ecosystem services upstream which influence the quantity and 'quality' of incoming wastewater. The latter is strongly influenced by the volumes and the contents of rainwater run-off which is linked to two types of ecosystem services: first, the frequency and the intensity of precipitations (climate regulation), and the regulation of water flows within urban ecosystems.

Ecosystems play a crucial role in the regulation of climate at local and global levels. By either sequestering or emitting greenhouse gases, they influence climate globally. At a local scale, the evapotranspiration process of the vegetation drives the hydrological cycle recycling rainwater back to the atmosphere and influences energy flows, vertical profiles of temperature and humidity which have key regional effects on climate and precipitations (MA 2005; Avissar et al. 2004). With respect to the regulation of water flows, the presence of vegetation reduces the fraction of rainfall going into runoff. In vegetated areas, there is only 5 to 15% of runoff, as most rainfall either evaporates or infiltrates into the ground. In vegetation-free cities, because of impermeable infrastructures, around 60% of rainfall becomes surface-water run-off which results in increased peak flows of urban wastewater (Bolund and Hunhammar, 1999).

The pollution load of water runoff is significant. Over an annual period, run-off water can bring a quantity of suspended solids equivalent to the load of pure wastewater (Table 5) and typically carries nitrates and

[6] Analyzing purchased biodiversity inputs would be more relevant for a case study involving a retailer.

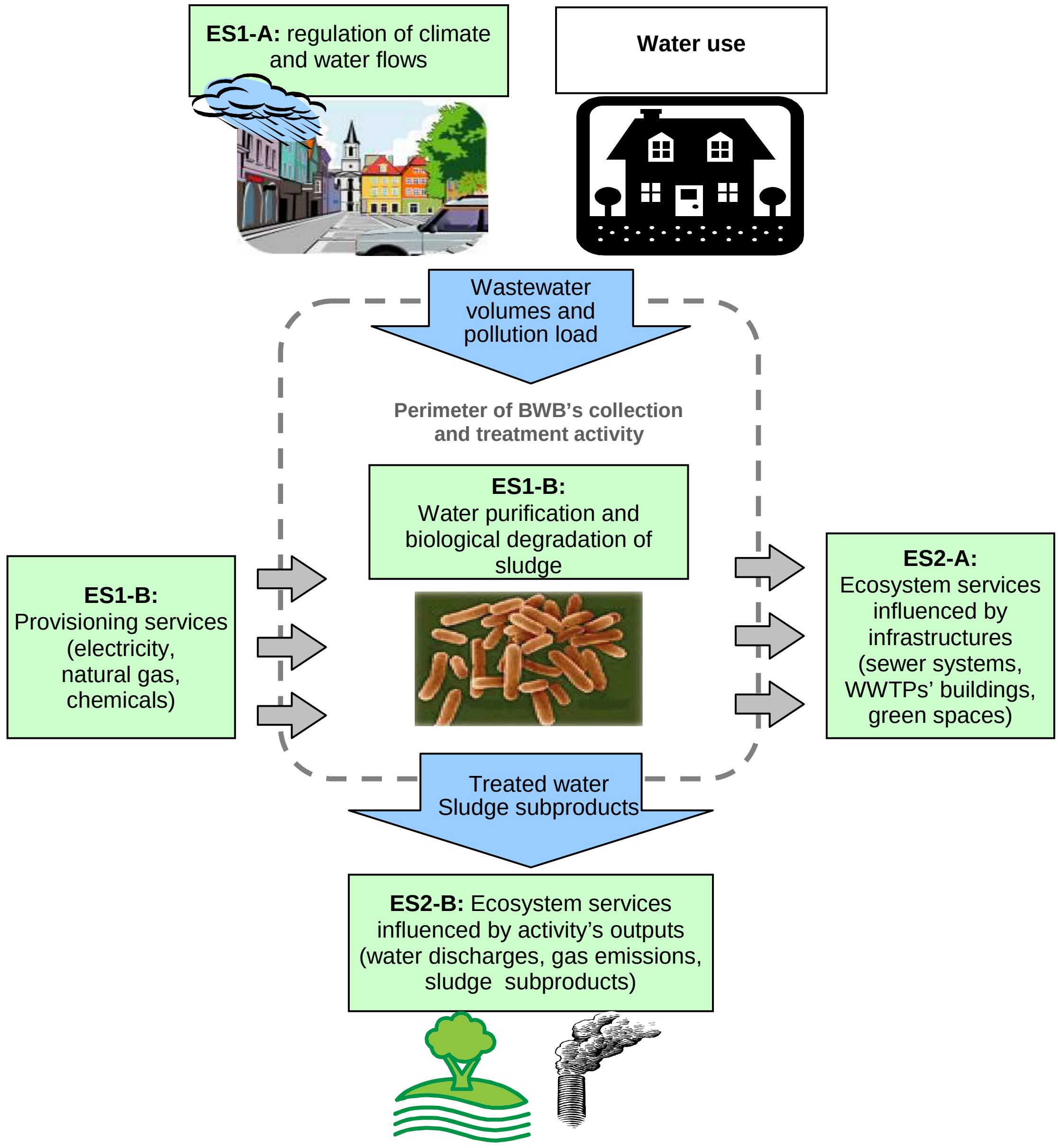

Figure 5: Interactions with ecosystem services

ammoniac (from fertilized soils), heavy metals, nitrogen oxides, oils and hydrocarbons (road traffic) (Bourrier, 2008; Haughton and Hunter, 1994).

At the present time, rainwater run-off collection and treatment in Berlin is assessed to cost between 200-250 M€ per year (between 1.4 and 1.8 € per m^2 per year). This amount includes (a) the transport and treatment costs of rainwater collected by the separate sewer system, (b) the transport and treatment costs of rainwater within the combined sewer system and (c) the investments necessary to adapt the dimensioning of the plants. At the level of Wassmannsdorf's plant, **the costs of rainwater treatment represent around 10% of total costs**.

Table 5: Comparing the pollution load of wastewater and water run-off (Bourrier 2008, p. 236)

	Suspended Solids (kg/ha/year)	5 day-BOD (kg/ha/year)	COD (kg/ha/year)
Water run-off	300 – 3 000	30 – 100	200 – 1 000
Wastewater	3 000	2 000	3 000 – 4 000

ES1-B corresponds to the ecosystem services controlled by management at Wassmannsdorf's WWTP. These may de differentiated into two types:

- Aforementioned material inputs (section 5) relate to ecosystem service benefits which are purchased so as to achieve organizational targets. These are imported from elsewhere (produced at other locations) and may be categorized as provisioning services (MA 2005). For instance, purchased natural gas represent 11% of total operating costs whilst purchased chemicals, which may contain various components extracted from ecosystems, make up about 2% of costs.
- Wastewater purification and sludge degradation by various functional groups of micro-organisms. While **40%** of **overall operating costs** are linked to the **management of the water treatment process**, the remaining share of costs **(a massive 60%)** can be attributed to the **management of sludge** (digestion, dewatering / drying and disposal), a direct output of the activity of micro-organisms.

The ecosystem services used for biological treatment of wastewater play a major role in the performance of the activity, both in terms of cost-efficiency and service quality. Indeed, wastewater treatment deals essentially with the management of these ecosystem services and their resulting outputs (treated water, sludge and biogas). It is a highly automated process: 30% of labour costs are assigned essentially to water quality monitoring at the outlet. Besides, the treatment of wastewater requires high levels of electricity inputs (about 50% of the total energy expenses) so as to circulate the water between the different steps of the process and maximize the availability of oxygen in the aeration tanks.

Sludge production is a direct output of wastewater biological treatment and is strongly correlated to the volume of treated water and its pollution load. This industrial process (electro-mechanical equipments) mobilizes 70% of labour costs and 50% of energy expenses (consumption of gas by sludge rotary driers). Biogas produced by sludge biological degradation generates additional revenue for the activity (2 to 2.5% of the total income at Wassmannsdorf's plant).

ES2-A relates to ecosystem services influenced by wastewater collection and treatment infrastructures, including sewage systems (collection network), built areas at WWTPs and non-built areas managed by BWB (e.g. green spaces at Wassmannsdorf's WWTP).

The current nature of the contract between the various parties for setting up BWB (section 1) entails specific performance assessment criteria and wastewater infrastructures which influence urban ecosystems. These currently involve essentially impermeable areas which may be linked to the loss of ecosystem services. However, BWB's role in these choices is often at best partial: it is contingent to various stakeholders responsible for decision-making with respect to wastewater infrastructure and land-use policies (Land of Berlin). Further studies would be needed to characterize these influences and would require detailed spatial analysis.

In the case of Wassmannsdorf's plant, which covers around 1 km^2, land management falls within the responsibility of BWB. Around half of this surface area is built-up while the other half is constituted of green spaces. These green spaces may provide a variety of ecosystem (dis-)services to other land-users around the plant, including farmers. A subcontractor is in charge of their management (less than 1% of total operating costs).

ES2-B refers to the ecosystem services influenced by the outputs of Wassmannsdorf's plant: water discharges, direct gas emissions, sludge subproducts and wastes. Though the latter two influence ecosystem processes, we choose to focus our analysis on out-flowing water.

The quality of treated water is closely monitored to satisfy standards set by the Land of Berlin on the basis of EU legislation (Table 3). **40% of total operating costs** contribute directly to achieving or improving such outcomes. Water discharges influence the various ecosystems downstream. Two different outlets are used, the Teltow canal and drainage ditches.

85% of the treated wastewater (1.86m^3/s) is discharged into the Teltow canal, a regulated channel used for ship traffic. This canal receives the effluents from three WWTPs (Wassmannsdorf, Stansdorf and Ruhleben during summer for swimming purposes) as well as Combined Sewer Overflows (CSO) during rainstorms[7] and effluents from two power plants (responsible for temporary increases in water temperature).

Since 1997, the remaining treated wastewater (0.35m^3/s) is discharged into drainage ditches constructed in 1989. These lead to the small river Nuthe via the ditch Nuthegraben, which is situated in a lowland area. In 2000, a pilot project was carried out to close the water cycle by bringing the advanced treated wastewater via ditches (Zülowkanal and Nottekanal canals) to the Dahme River upstream of Berlin. Studies have been carried ex-post to assess the impacts on water balance and soil conditions as well as on agriculture and forestry (Heinzmann 2007).

Yet, further studies would be needed to fully characterize the influences of water discharges into these two outlets with respect to both biodiversity (as a cultural ecosystem service) and ecosystem services[8] used by other land-users. This would also require detailed spatial analysis.

Information available at Wassmannsdorf's plant fails to fully inform us of the nature of interactions between BWB and BES. To understand the latter would require further research to develop sets of indicators regarding how BES change throughout the ecosystems with which BWB interacts, which goes beyond the scope of this case study. Nonetheless, important conclusions can be drawn and will be discussed in the last section.

7. How may BWB systematically take biodiversity into account within its corporate strategies?

According to a report by the French *Commission des comptes et de l'économie de l'environnement* (2005), wastewater expenses are categorized as 'environmental expenses' within the national accounts. By providing some understanding of the interactions between a Wassmannsdorf's wastewater treatment plant and biodiversity and ecosystem services, this case study suggests that this classification may be inappropriate at the business level from an ecosystem perspective:

[7] In case of exceptionally large volumes of rainwater, the total volume of water to be treated can exceed the total capacities of the plants. In such situations, norms require that the full volume of wastewater from the separate network must be treated, so that the exceeding volume is directly discharged from the unique network into the Teltow canal.

[8] For a list of potential of ecosystem services in inland water systems, see Annex 1.

more precise accounting information with respect to BES are needed so as to rigorously assess firms' ecological performance. What would it mean for other industries which depend and / or influence various ES? We argue that this opens the door for management accounting information systems categorizing costs and revenues according to the ES the business depends on and / or influences. Besides, this may have significant implications in terms of environment-related costs and revenues companies listed on stock exchanges publish within extra-financial reports.

Furthermore, Houdet et al. (2009) identifies three interacting and potentially overlapping business management interfaces with respect to biodiversity and ecosystem services:

- Interface 1: managing BES sources, delivery channels, timing of delivery and benefits to business.
- Interface 2: assessing business responsibility to BES, which is two-pronged:
  - Managing issues which fall under its legal control or refer to contractual terms;
  - Managing issues through stakeholder engagement (suppliers, clients, local communities).
- Interface 3: managing its impacts on BES, both positive and negative.

From a management accounting perspective, we have shown that BWB management is currently mainly involved with the management of interfaces 1 and 3 at Wassmannsdorf's WWTP. With respect to interface 1, BWB's business is mainly concerned, in contractual terms, with:

(a) the management of ecosystem services within wastewater treatment plants, that of water purification (40% of total operating costs at Wassmannsdorf's plant) and sludge digestion (60% of total operating costs are related to sludge management, a significant share of which involves the digestion process) by micro-organisms (ES1-B), and

(b) the quantity, content and delivery timing of wastewater entering WWTPs, which is influenced by various ecosystem (dis-)services within urban areas upstream (ES1-A).

Regarding interface 3, Wassmannsdorf's plant must satisfy water quality standards at its outlet. Yet, these standards refer to partial drivers of BES change downstream (incomplete criteria with respect to ecosystem services used by others downstream, including biodiversity as a cultural ES; ES2-B) and, in addition, do not account for the influences of wastewater collection and treatment infrastructures (e.g. sewage systems, built and non-built areas) on ecosystem services (ES2-A).

From this perspective, how can biodiversity become a key strategic variable for decision-making? We argue that the key challenges to taking biodiversity into account at all strategic levels relate to interface 2: contractual terms do not directly take into account BES (i.e. no policy and quantified / specialized targets) and there is no standardized and systematic stakeholder engagement with respect to the interactions between BWB's business (WWTPs, waster collection and sewage networks) and BES.

Accordingly, we identify three principal and complementary approaches which could be systematically explored, as part of BWB's core strategies, towards promoting the diversity, variability and heterogeneity of living systems (Houdet et al., 2009b) throughout the ecosystems with which the company interacts:

A. Integrating green spaces managed by BWB into local ecological networks: for instance, Wassmannsdorf's green spaces could be managed ecologically (differentiated green spaces management, e.g. Venn 2001) and links with important ecological areas nearby could be explored in partnership with stakeholders (Annex 2). Costs of differentiated management of green spaces typically include: (a) an initial investment for feasibility studies (around 6500€ for a 4 hectares site with 40% of green spaces), (b) optional annual monitoring costs (2 000€/year), and (c) recurring maintenance costs similar to those of conventional green areas management[9].

B. Promoting ecological engineering techniques (e.g. Albaric 2009; Byers et al., 2006; Kadlec and Wallace, 2009; Toet et al., 2005) throughout wastewater infrastructures with BES targets co-constructed with stakeholders, notably the Land of Berlin and adjacent users and land-owners. Provided the right planning and decision-making framework is set in motion (Jewitt 2002; Strange et al., 1999), redesigning wastewater infrastructures and/or implementing additional ecological engineering fittings could lead to improved ecosystem services delivery to various groups of users. For instance, the installation of floating planted islands in the waterway downstream of the plant can remove residual pollutants including heavy metals (Headley 2006; Sun 2009), provide habitat for several species from microbes to birds (Nakamura 2008) and may beautify the landscape; and this at a cost limited to 65€/m^2 (Albaric 2009).

C. Including complementary contractual BES performance criteria into BWB's contractual terms: negotiated with stakeholders, these new criteria would require finding appropriate financing mechanisms (e.g. for investments), and may lead to changes in sources of income, as BWB could also be remunerated for practices which promote simultaneously biodiversity and various ecosystem services throughout the water and wastewater networks.

To conclude, because some other BWB's plants have already tested or applied some of these complementary approaches, collecting information and identifying best practices would be highly useful[10] as part of further studies which would aim to systematically explore alternative strategic options and assess their feasibility.

[9] Decreases in purchases of phytosanitary products may be compensated by increases in labour costs. In most cases, the balance between these two variations is not significant in the budget of a WWTP (internal documents, Veolia Environnement).

[10] This work does not fall within the scope of the present case study.

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9. Annexes

Annex 1: ecosystems services derived from inland water systems (chapter 20, MA 2005, p. 554).

Services	Comments and Examples
Provisioning	
Food	production of fish, wild game, fruits, grains, etc.
Freshwater[a]	storage and retention of water for domestic, industrial, and agricultural use
Fiber and fuel	production of logs, fuelwood, peat, fodder
Biochemical	extraction of materials from biota
Genetic materials	medicine, genes for resistance to plant pathogens, ornamental species, etc.
Biodiversity	species and gene pool
Regulating	
Climate regulation	greenhouse gases, temperature, precipitation, and other climatic processes; chemical composition of the atmosphere
Hydrological flows	groundwater recharge and discharge; storage of water for agriculture or industry
Pollution control and detoxification	retention, recovery, and removal of excess nutrients and pollutants
Erosion	retention of soils
Natural hazards	flood control, storm protection
Cultural	
Spiritual and inspirational	personal feelings and well-being
Recreational	opportunities for recreational activities
Aesthetic	appreciation of natural features
Educational	opportunities for formal and informal education and training
Supporting	
Soil formation	sediment retention and accumulation of organic matter
Nutrient cycling	storage, recycling, processing, and acquisition of nutrients
Pollination	support for pollinators

Annex 2: Aerial view of the area surrounding Wassmanndord's WWTP, highlighting different categories of protected areas (Google Maps; World Database on Protected Areas: http://www.wdpa.org/).

Landscape Protection Area, UICN Category V

Nature reserve, UICN Category IV