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Accounting for the water purification ecosystem service

Authors: Alessandra La Notte (Joint Research Centre of the European Commission), Bruna Grizzetti (Joint Research Centre of the European Commission), Silvia Ferrini (University of Siena and University of East Anglia), Sergio Vallesi (Durham University)

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1. Description of the water purification ecosystem service

Ecosystem-based water purification can be considered as a sink-related service (La Notte et al. 2019a), whose flow strongly depends on the type and amount of pollutants emitted directly into water bodies either directly or indirectly, e.g. via percolation through soil (flowing then into water bodies). Starting from its definition in current classification systems, our description of ecosystem-based water purification will thus focus on the pollutants, processes and ecosystems involved.

1.1 Definition of water purification service in international classifications and conceptual frameworks

The ecosystem service water purification refers to the removal of pollutants from water that is mediated by microorganisms, algae and plants and other ecosystem processes such as filtration, sequestration and storage[1]. In the Millennium Ecosystem Assessment (MEA 2005) water purification and waste treatment are considered benefits obtained by regulating ecosystem processes, which contribute to human well-being by securing access to and availability of clean water. This service depends on the intrinsic self-purification capacity of the ecosystems, which filter out and decompose wastes introduced into inland waters, coastal and marine ecosystems. In the Economics of Ecosystems and Biodiversity methodological framework (TEEB 2010) the service is mainly classified under the waste-water treatment class, which refers to the capacity of soil and wetlands microorganisms to detoxify pollutants and decompose waste. In the ongoing IPBES assessment (Diaz et al 2015), water purification services should be mainly included in the reporting category of nature's contributions to people "Regulation of freshwater and coastal water quality" (e.g. the regulation by ecosystems or particular organisms of the quality of water by filtration of

[1] According to many ecologists this definition is a simplification that can be accepted once its assumptions are acknowledged. The main argument is about the concept of ecosystem services, founded on a closed system assumption and a sequential cause and effect logic, while scientific evidence clearly demonstrates that are no closed systems in nature, and that time is neither constant nor linear. Furthermore, nature evolves as a coevolution of communities, and recent discoveries of multilateral transfer of genetic materials makes genotypes as continuums and no longer compartments (Tane, 1996).

particles, pathogens, excess nutrients, and other chemicals) (IPBES/5/INF/6, Progress report on the guide on the production of assessments, March 2017). Finally, in the Common International Classification of Ecosystem Services (CICES v5.1, consistently with its previous version CICES v4.3, 2013) the water purification service is among the regulating and maintenance (biotic) services, classified in the groups Mediation of wastes or toxic substances of anthropogenic origins by living processes and Water conditions. Indeed, under the first group the CICES v5.1 mentions, for example, the filtration by macrophytes and in the second group it makes references to the removal of nutrients in buffer strips along water courses. However, it has been noticed that for bio-remediation and water quality maintenance services there are overlapping classes in CICES that are hard to discriminate in a practical assessment context (Czúcz et al. 2018).[2]

1.2 Water purification: pollutants, processes and ecosystems involved

The water purification service is associated to the need of water quality for human well-being and ecosystem health. Water quality requirements are generally defined according to specific water uses, such as drinking, domestic supply, recreational activities, aquaculture, irrigation, livestock, industrial cooling, etc. Sufficient water quality standards are also needed for maintaining the natural habitat and biodiversity of water ecosystems and sustaining the aquatic life. Elements impairing water quality can affect its microbiological characteristics, such as pathogens and coliforms, or alter its chemical composition. Sediments, nutrients, organic matter and metals, are naturally present in the water medium, but their excess, due to agricultural practices or human domestic and industrial wastes, can strongly affect the aquatic environment. Similarly, man-made chemicals, such as synthetic compounds, plastics, pesticides and pharmaceuticals, once discharged in waters pose harm to human and ecosystem health.

Different processes contribute to water purification, depending on the type of pollutant and the ecosystem involved. Water purification can take place in soils, groundwater, wetlands, rivers, lakes, estuaries, and in coastal and marine environment[3]. Indeed, in a river basin the fate of pollutants depends on the processes of transport and transformation associated with the hydrological water cycle. In soils, water-dissolved chemicals and organic matter can be decomposed by fungi and bacteria. Vegetation in forests, natural grassland and wetlands has the important role to slow down the movement of water, thereby favouring the biological processes. Metals, sediments and chemicals are filtered out and adsorbed by soils particles in wetlands and riparian areas. Some plants and macrophytes have also the capacity to uptake toxic compounds, improving water quality. Pathogens are degraded by microorganisms in soils and groundwater. Nutrients (nitrogen and phosphorus) can be reduced by algae and plant uptake in aquatic ecosystems and wetlands. In particular nitrogen is also lost to the atmosphere by the process of denitrification operated by bacteria in anoxic conditions (Saunders and Kalff, 2001), which can occur in soils, wetlands, groundwater, hyporheic zones, riparian areas, and in sediments and in the water column of lakes, estuaries and large rivers (Seitzinger et al. 2006).

Thus the water purification service affects different pollution sources and types, involves several chemico-physical and biological processes of removal, and can take place in both aquatic and terrestrial ecosystems. These aspects explain the complexity of assessing this service. In addition, the relevance and type of pollution is different according to local geomorphological features and in relation to the different general economic sectors of the area. For example, nitrogen pollution and aquatic eutrophication are

[2] UKNEA (2011) stresses the importance of valuing final ecosystem services rather than intermediate services an water purification can be both accordingly to circumstances.

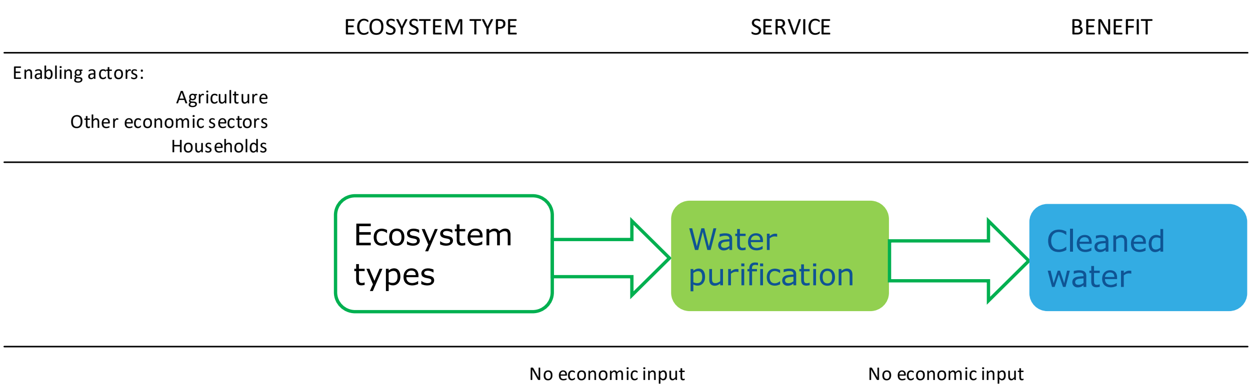
[3] One of the most powerful places where water purification takes place on earth is floodplains. Unfortunately, these have almost disappeared in urbanised areas, and with it the ability to purify water.

of greater concern in industrialised countries, where agriculture is intensive and domestic waste and drinking water generally receive adequate treatments, while pathogens and coliforms are of major concern in countries with poor sewage treatment facilities, other sanitation infrastructures or drinking water treatment plants, and contamination from metals or specific chemicals can be relevant in urban and industrial areas.

2. The accounting frame for water purification and its peculiarities

The ecosystem service accounting system is based on the supply and use tables (SUTs). Figure 1 shows which components of SUTs that will be relevant for water purification. Ecosystem types include: urban, cropland, grassland, forest & woodland, heathland and shrub, sparse vegetation, wetland, rivers and lake. It does not include marine, although it is indeed relevant since all the pollution that is not mediated by terrestrial ecosystems will end up in the sea.

Figure 1 – Water purification logic chain for accounting



On the left-hand side, we can find the main components that will structure the supply table: ecosystem types. As previously mentioned, water purification takes place in soil and water: the ecosystem types that will provide the service flow are shown in Figure 2. The ecosystem types include the component of the water purification service that takes place in soil. In fact, soil can play a double role: as "sink" service (i.e. soil decontamination) can mediate the pollution, as "buffer" service (i.e. component of water purification) can reduce the magnitude of unmediated flows that ends up into rivers and lakes. To identify the role of ecosystems in delivering different typologies of services can be of help from an accounting perspective (ref to Annex I for a summary table).

The amount of pollutants unmediated by soil passes to the ecosystem type "rivers and lakes", which includes the "sink" component of the water purification service that takes place in inland waters. The amount of pollutants that is not mediated by inland waters ends up into the sea. If water catchments were unable to mediate pollutants (because too degraded) the river network would become a passive corridor that makes the pollutants flowing directly into the sea.

Figure 2 – Supply table for water purification

	Institutional sectors											Ecosystem types								
	agriculture	forestry	fisheries	mining and quarrying	manufacturing	construction	electricity, gas supply	water collection,	treatment,supply	other industries	households	urban	cropland	grassland	forest & woodland	heathland & shrub	sparse vegetation	wetland	rivers and lakes	marine
water purification												X	X	X	X	X	X	X	X	

The use table is more articulated. As previously mentioned, a first peculiarity of water purification is to involve different sources of pollution: the water purification “enabling actors” represent the emitters of pollution. Their action determines the amount of the service flow and any change that occurs in the actual flow of the service depends primarily on them (La Notte and Marques, 2017). Because of the negative impact they generate, polluting sectors will be named “enabling pressures”. Any policy meant to address the issue of sustainability of water purification and avoid the degradation of freshwater ecosystems should address the causes, i.e. enabling pressures. The final beneficiaries of water purification are the sectors that need clean water, e.g. to lower their cleaning costs before distributing it (water supply companies, water based recreationists, etc.) or for their own final use (households) or intermediate use in production (farms and businesses). The use table could thus be split into two components: the *complementary* part where the service flow is attributed to the enabling pressures served by the cleaning process and the *official* part where the service flow is attributed to the final beneficiaries (Figure 3). In fact, there are two kind of beneficiaries: direct beneficiaries enjoy the “cleaned” outcome of the sink process, and indirect beneficiaries are allowed to pollute as long as ecosystems clean. About the latter: if ecosystems did not assimilate emissions, the polluting sectors would face much stricter regulations on emissions and would incur in penalties. From this perspective, industries are benefitting from the role that ecosystems are playing in storing/absorbing emissions.

Moreover, the reason that makes the *complementary* part needed is that what affects the service flow amount and any changes that occur over times is how much enabling pressures pollute and not how much final beneficiaries (i.e. cleaned water users) consume. We need to keep in mind that the service provided is the removal/retention of polluting substances and the outcome of the service is cubic meter of *cleaned* water. We thus need to distinguish between the two ecosystem services characterized by two different ecological processes, i.e. water supply (making water available) and water purification (cleaning water).

Please note that many sectors are not marked as final beneficiaries because: they need water and not *cleaned* water (e.g. Hydroelectricity within “electricity and gas supply”); they buy *cleaned* water from water supply companies (within “water collection, treatment, supply”) and this part of the process in accounted as intermediate consumption in the SNA (e.g. the whole secondary and tertiary sectors). Agriculture and Households have been marked as final beneficiaries only for what concerns own extraction (any other use is considered as purchased from water supply companies).

Figure 3 – Complementary and official use table for water purification

	Institutional sectors										Ecosystem types								
	agriculture	forestry	fisheries	mining and quarrying	manufacturing	construction	electricity, gas supply	water collection, treatment, supply	other industries	households	urban	cropland	grassland	forest & woodland	heatland & shrub	sparse vegetation	wetland	rivers and lakes	marine
water purification	X	X		X	X	X			X	X									
(enabling pressures)																			
cleaned water	X							X		X									
(final beneficiaries)																			

Another important peculiarity of the service is the misleading meaning of the actual flow in a sustainability perspective: the higher the pollution, the higher the actual flow, the higher the value attributed to the service. This logic cannot serve the aim of sustainability assessment or be used to calculate the ability of the ecosystem to provide the service in the long-term. This happens because when the actual flow exceeds certain thresholds it implies overuse and eventually leads to permanent degradation of inland waters. Inland waters have in fact an absorption rate that should not be exceeded (La Notte et al., 2019a) and is determined by local conditions in water sub-catchments. In a previous application of water purification accounts (La Notte at al., 2017) a sustainability threshold was established at 1mg/l considering the risk of eutrophication and looking at the scientific literature available on the topic. For each sub-catchment the potential flow of water purification was calculated by considering this sustainability threshold. Any mismatch where actual flow is higher than potential flow signal potential overuse and increases the risk of permanent degradation: **potential flow and mismatch accounts** can be used as complementary information to be added to official accounting tables to support policy makers in sustainability assessment (La Notte and Dalmazzone, 2018).

Based on policy targets established in regulations and directives (e.g. the Nitrates Directive and Water Framework Directive in Europe, the Clean Water Act in USA, the Water Pollution Prevention and Control Law in China), different sustainability thresholds could be set to assess compliance with the target. According to this perspective, policy targets representing interests and wellbeing of the community become the users of the water purification service: **complementary accounts assigning the actual flow to enabling pressures** (the likely target of policy action) would again complete the water purification set of information by providing policy maker with a revealed causality nexus in the accounting chain. This third feature builds upon the previous two.

Finally, in Figure 1 (and in turn in Figure 3) the flow chain highlights two distinct phases: (i) the process of cleaning water as ecosystem service that can be expressed as tons of pollutant removed and (ii) the outcome of the process itself as cubic meters of cleaned water. This distinction is important when deciding what to value and how.

3. Biophysical assessment of water purification

In large scale assessments nitrogen retention has been adopted as proxy to quantify the service of water purification (La Notte et al. 2015; 2018; Sharp et al. 2015, Liquete et al. 2015). Nitrogen retention is defined as the removal of nitrogen in the water system (Howarth et al 1996; Billen et al 2011). One of the reasons for this choice is the wide spread problem of excessive nitrogen (and phosphorus) loadings to aquatic ecosystems, which causes the disproportionate growth of algal biomass and consequent hypoxia and collapse of the ecosystem (ref). This phenomenon of eutrophication has been observed in estuaries and coastal waters, and can occur also in shallow lakes and large river reaches, receiving high anthropogenic nutrient loads from the river basin, both from diffuse (agriculture) and point pollution sources (discharges from waste water treatment plants, industries and urban sewages) (Diaz et al. 2017). It is mostly linked to the simultaneous increase of the nitrogen and phosphorous, since a given ration is needed for algal proliferation. As a consequence, recreational activities and natural aquatic biodiversity are compromised. High nitrate concentration in groundwater, due to an excessive use of nitrogen fertilisers used in agriculture, also impairs water for drinking purposes. Assessing nitrogen retention in the water system implies computing the nitrogen budget (input minus output), at the relevant spatial and temporal scale.

Hydrological and biogeochemical catchment models are appropriate tools for assessing water ecosystem services related to water, as they can take into consideration the sources and location of pollution, the hydrological processes and the different pathways. They can also offer the possibility to predict the effects of land use, management practices and climate changes on water quality (Guswa et al 2014; Vigerstol and Aukema 2011; Brauman et al. 2007). However, their application can be demanding in terms of data, time and expertise (Vigerstol and Aukema 2011). Several models are available in the literature to quantify nitrogen and other quality parameters. Importantly the choice of an appropriate biophysical model to estimate the water purification should account for the spatial scale and temporal resolution of the analysis and the availability of data and expertise. The model **SWAT** (Soil and Water Assessment Tool) has been extensively used for modelling water quantity and quality in river basins, and for assessing the impact of agricultural management strategies and climate change (Arnold et al. 1998). It allows assessing sediments, nutrients and pesticides in the river basin streams, on a daily time-step and at high spatial resolution (catchments, grids). It has been used for quantified different ecosystem services, in particular water provisioning and water purification (Francesconi et al. 2016). The model **InVEST** (Tallis and Polasky, 2009) was developed explicitly to map and also valuate different ecosystem services, including water purification, which in the model is represented by the proxy nitrogen retention. In large scale assessments, the quantification of nitrogen retention has been carried out using conceptual models, such as **GREEN** (Grizzetti et al. 2012, La Notte et al. 2018) and **GlobalNEWS** (ref). These models are less complex and data intensive than SWAT, and provide annual estimates. Other examples of models for quantifying nutrient loadings in river basins are **MONERIS** (Venohr et al. 2011), **RiverStrahler** (ref), **INCA** (ref). (For a discussion on the challenges of assessing nitrogen retention in the river system and suitable modelling tools see Hejzlar et al 2009 and Grizzetti et al. 2015). Modelling tools exists also to assess pathogens (fecal coliforms) loadings and have been applied at the catchment level and been used for assessing water purification from pathogens (for example INCA-pathogen, Rankinen et al 2016) at the regional scale (for example WorldQual, Reder et al 2015; 2017).

As different suitable models are available in the literature to quantify nitrogen and other water quality parameters, it is more important to focus on the indicators obtained rather than on the tools to carry out the biophysical assessment (Grizzetti et al. 2016). Grizzetti et al. (2016) reviewed a number of studies on indicators of water ecosystem services, including water purification, (Maes et al. 2014; Egoh et al. 2012;

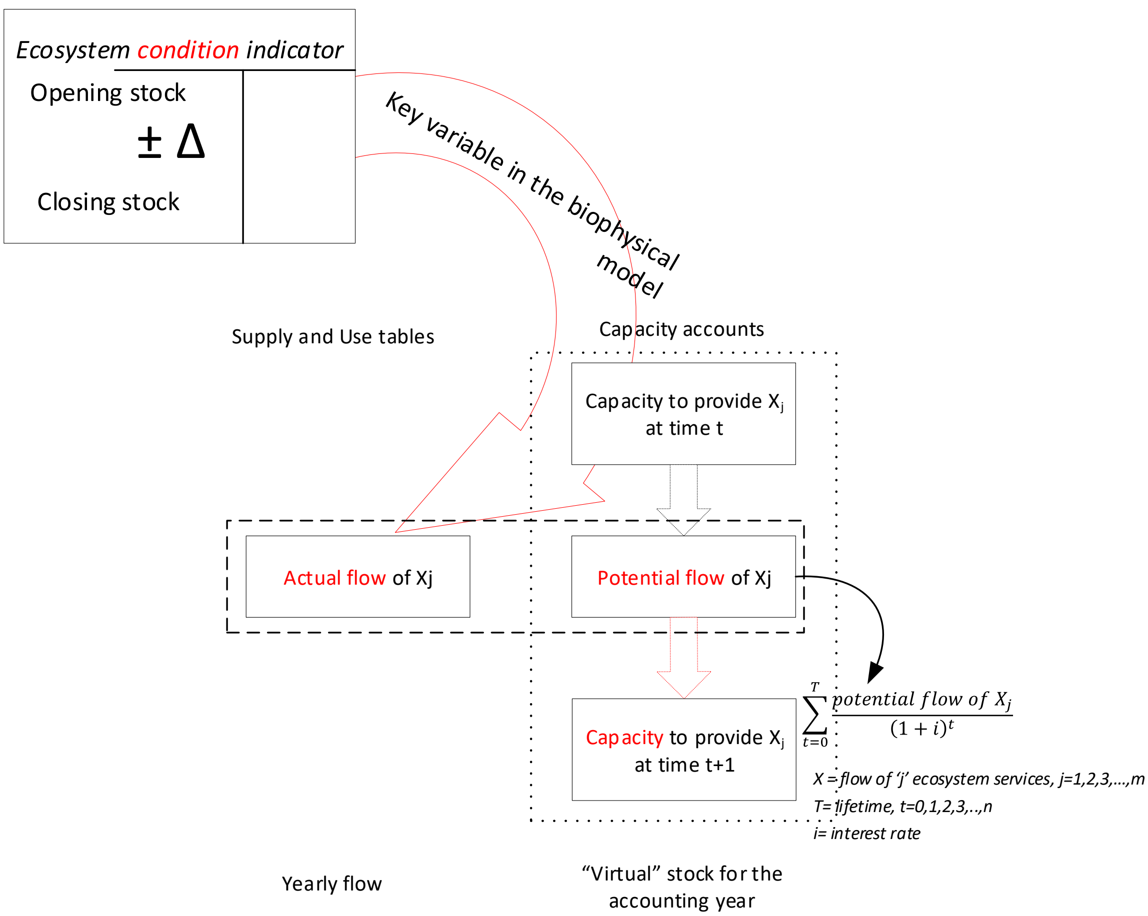
Layke et al 2012; Liquete et al. 2013; Russi et al. 2013), and classified the indicators according to the aspect of the service represented.

4. Linkages of water purification flow with Capacity and Conditions

Humans' activities produce pressures on the aquatic environment altering its condition, biodiversity and functioning; at the same time the ecosystem condition influences the delivery of services to people (Keeler et al. 2012; Grizzetti et al. 2016). Understanding the relationships between pressures, state and provision of services is complex.

In accounting terms, a linkage exists between ecosystem condition, service and capacity for water purification. For example, in the EU initiative Mapping and Assessment of Ecosystems and their Service (MAES), "Concentration of nutrients and biological oxygen demand in surface water (ml/l)" is among the indicators for ecosystem condition (Maes et al., 2018). From the way condition accounts are structured, it is possible to recognize a linkage between the indicator for which the asset balance is built and its role as key variable in the biophysical model assessing the service flow (Figure 4).

Figure 4 – Linkage of SUTs with condition and capacity accounts for water purification



Source: adapted from La Notte et al. (2019b)

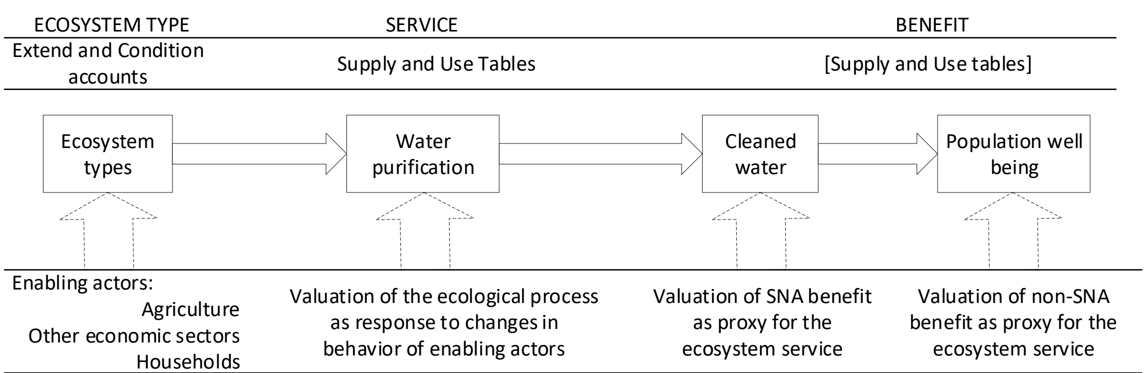
From the biophysical model it is possible to calculate potential and actual flow. The latter will populate official SUTs; the former can be used to calculate capacity in monetary terms, as Net Present Value (the NPV approach is suggested in UN. 2017). It would be important to calculate the capacity from the potential flow because this allows to account for service overuse that eventually leads to degradation (La Notte et al., 2019a). If calculated from actual flow, a too high, unsustainable use of water purification will misleadingly show a high NPV, and in turns a high capacity. Figure 4 presents capacity as "virtual stock" of water purification. In fact, it is not possible to quantify the total capacity of the ecosystem for water purification, but increasing pressures on the ecosystem (as increasing pollution) degrade the capacity of the ecosystem to provide regulating services. Evidence shows that 'humans have altered the waste processing service by exceeding the capabilities of the ecosystems to provide the service' (MAE 2005). For this reason it is important to reflect upon the sustainability of the water purification service in the long-term. A possibility is to set water quality thresholds that allow the maintenance of good ecological conditions of the water ecosystem.

5. Monetary valuation of water purification

The valuation of ecosystem ability to purify water could take place at different stages (Figure 5). When deciding which kind of valuation to apply, it is import to consider the object of valuation:

- -the service flow, in this case considered as final service (second arrow of Figure 5);
- -the benefit generated by the service; in this case the service flow is intermediate to another output (third and fourth arrow of Figure 5).

Figure 5 – Logic chain adapted for valuation purposes



This decision depends on the purpose of valuation and is going to affect strongly the valuation method to be applied. In any case, the valuation method should be linked and should depend on the biophysical model to translate any change driven by human pressure in monetary terms.

In general terms, the valuation of human activities on water purification can be valued in line with SNA exchange value concept; this is true for the water purification as nitrogen removal process (second arrow in Figure 5) and for the impact of water purification on the availability of cleaned water (SNA benefit, third arrow in Figure 5). Differently, the impact on components of human well-being (non SNA benefits, fourth arrow in Figure 5) might require approaches based on individual preferences rather than transaction prices. Also the impact on human health (as non SNA benefit, fourth arrow in Figure 5) could be taken as monetary proxy for the water purification service, however specific epidemiological studies on the effect of clean water on human health are not available.

While some studies focus directly upon water purification others consider water quality protection benefits or a suite of benefits (arising from say, the conservation of green spaces, biodiversity and habitat preservation), or relate it to broadly defined water quantity and quality. The Ecosystem Service Valuation Database and the ValueBase SWE have been interrogated for “water purification” but few studies provide relevant information for water purification accounting. An ad-hoc research system in Scopus, WoS and Google Scholar has been conducted to retrieve the most recent and relevant applications on water valuation for accounting.

Some of these studies present water-related ecosystem services accounts: Remme et al (2014, 2015) Duku et al. (2015), Pedro-Monzonís et al (2016), Borrego-Martin et al (2016), Bujnovsky (2018) and Lai et al (2018). The majority of these studies stresses the nexus biophysical model-economic measures and accounts. Duku et al describe the pathway to accounting but they do not provide any valuation of water purified services whereas Pedro-Monzonís et al 2016 focus on water account tables and stress the difficulty in accessing reliable economic measures for monitoring transboundary river basins. Borrego-Martin et al (2016) seem to suggest a shortcut to data availability as they propose a cost recovery approach for valuing water services. The recovery costs for water services are reported at the EU level and the authors suggest a partitioning system based on SNA water players to estimate water measures. However, they acknowledge that this approach is not viable to account for diffuse pollution as the existing cost recovery instruments are not including nitrogen phosphate for example.

Lai et al and Remme et al provide instead values mainly related to abstracted water. Lai et al present a value for nitrogen concentration in surface water that is worth between 190/203 SEK mg/litre but details of the method used are missing. Bujnovsky 2018 reports the first Slovak inland water ecosystem services accounts and water purification is valued using production costs for water treatments (e.g. replacement costs) equivalent to 0.11 Euro/m3. Although the study is comprehensive in considering the water accounting sectors the link with biophysical models and the reliable economic data is very lose. The author concludes saying that “the evaluation of the benefits from ESSs of inland waters in Slovakia so far does not allow direct use of obtained results for proposal of measures within river basin management plans” as such more work is needed before ecosystem services accounts can lead to policy decision-making.

While techniques such as replacement costs would directly tackle the valuation of water purification ecological process (Figure 1), other techniques such as production costs would derive marginal value of water in different sectors productivity (Figure 1, SNA benefit). The more we move away from exchange-value based techniques, the more we tend to refer to components of human well-being (it is the case of stated preference technique) and we thus refer to non-SNA benefits (Figure 1).

The other revised studies just focus on valuing the water purification service using a set of economic methods that suit the objective of the studies. So, for example, studies dedicated to minimize production costs of water purification services are using production costs, opportunity costs or avoided costs (Glen et al 2008, Zhang et al 2012, Collins et al 2018). Studies concerned with welfare impact of cleaned water are using revealed or stated preference methods (Bateman et al 2016, Hampson et al 2017). Estimated costs vary greatly reflecting the policy target to achieve, the spatial location of interventions and main sectors involved. For example in Glen et al 2008 we read that “at the 20 percent reduction of annual nitrogen minimum cost vary between 295 and 2245 millions of SEK, depending on target specification with respect to overall reductions or decreases in load to specific basins”.

Many other studies deal instead with water ecosystem services without a specific reference to SEEA accounting framework. Methods employed are mainly coherent with SNA rules as they are based on exchange prices such as production cost methods, preventive expenditure approach, payment for ecosystem services, restoration or replacement costs. Revealed and stated preference methods are also playing a role in valuing water services but values mainly capture welfare benefits (Hampson et al 2017).

Table 1 – Summary of valuation techniques for water purification

Valuation techniques for water purification	Description	Studies
Production costs	Estimates a mathematical relationship between the different inputs to water companies' service. This allows separating the role of any input in particular, such as water filtration.	Onofri et al (2017)
Preventive costs	Using costs to mitigate the utility loss from ecosystem services degradation	Shrestha et al 2018, Collins et al 2018, Zhang et al 2012
Replacement costs or Avoided costs	Using information on costs of manmade purification options. Alternative measures are either some form of improved waste water treatment or measures to reduce nutrient emissions from agricultural production.	Gren et al 2008, Grossman (2012), La Notte et al (2017)
Payment for ecosystem services or Payment for Watershed Services	Fiscal mechanisms designed to mitigate ecosystem services degradation	Huber-Stearns et al 2015, Grima et al 2016, Lopa et al 2012
Revealed preference methods	Direct market behaviours can reveal preferences for water characteristics that can be modelled with travel costs or hedonic price approaches	Bateman et al 2016
Stated preference methods	Surveys where individuals provide answers about choices related to environmental change or their willingness to pay for any such changes	Hampson et al 2017

Production cost methods require the availability of production inputs (e.g. cleaned water) over time and the modelling strategy needs to disentangle the marginal changes in output due to the water purification service. Onofri et al 2017 present an example of this approach but econometric identification problem, availability of data and intra-sectorial effects might impact the economic value. It is likely that this method can play an important role in valuing water purification services as more data become available although single industry costs are frequently kept private and aggregation error might undermine the reliability of water purification services.

Preventive cost methods like the set of farmers' activities presented in Collins et al 2018 and Zhang et al 2012 determine the investments needed to minimize the diffuse water pollution from the agriculture sector. In this case the investment needed to prevent the loss of water purification services represent the market value of the service. However, this value can although underestimate the transaction costs for farmers and in others overestimate the nutrients' management options as the multi-efficacy of combine technologies is not taken into account. A similar approach is proposed by Shrestha et al 2018 where the cost of in-house preventive technologies are installed by households (defensive expenditures). In this case the loss of water purification services lead to lower water quality that is moderate by installing technologies. Considering defensive expenditures from polluting sectors or final users can represent a strategy for water purification services but it is likely that estimates mainly reflect the availability of technologies, agriculture management practices and household education and wealth. In term of accounting the costs of these "preventive" technologies are already included in the SNA and the accounting in the water ESs might lead to potential double counting.

Replacement costs is surely the most popular technique to derive water purification values (e.g. Grossman 2012, Gren et al 2008, La Notte et al 2017). Grossman 2012 employs a cost minimization approach to identify the set of measures that minimize costs of water purification in river Elbe. Glen et al 2008 considers the cost of diverse land management strategies to reduce nitrites and phosphate in the Baltic Sea. The study tackle point and diffuse pollution sources costs. Aspects particularly relevant for valuing water purification services are the transboundary aspect of the hydrological systems, variation in land and industries discharge policies and the chain of effects on water retention function. The paper stresses the importance of considering a multi-sectorial approach in order to account for the total costs of nutrients and phosphate costs. La Notte et al 2017 chooses the hypothetical cost of constructed wetlands (CW) as the best way to translate in monetary terms the outcomes of the biophysical model: (i) by considering that what is discharged in the water bodies from point sources is coming also from Waste Water Treatment Plants, (ii) by differentiating CW costs for diffuse and point sources, (iii) by balancing the issues of economy of scale and of different raw material and labour costs.

Payment for ecosystem services represents a potential source of information for valuing water purification services as diverse projects have been implemented in several countries (Huber-Stearns et al 2015, Grima et al 2016, Lopa et al 2012). Many of these projects are small scale projects with a limited number of pressures and the payment reflect local conditions. In particular the institutional and management costs of PES might be quite relevant in explaining the different costs and this can pose challenges in attempting to monetize the water purification services for accounting. Alternatively to PES, the level of environmental tax for nitrate and phosphate can represent another proxy for water purification services. Lungarska & Jayet (2018) present an interesting application of spatially differentiated nitrogens taxes.

Exchange price approaches mainly focus on active SNA players and aim to detect the values of the ES through market transaction proxy (e.g. new technologies) or policy instruments (e.g. PES). Contrary the revealed and stated preference methods mainly focused on general public attitude towards environment and might capture use and non-use values.

Bateman et al (2016) present an integrated modelling approach to link the agriculture costs of reducing diffuse pollution, the water chemical characteristics and the population benefits for enjoying water quality. Economic estimates are provided via travel cost approach where the annual visitation rates and costs (including value of time) determine the water quality benefits. Hampson et al (2017) disentangle the recreation benefits of the general population for ecological and microbiological water quality. These values represent the willingness to pay value for water benefits derived by stated preference approaches. A relevant result of this study is the importance to account for economic and health impacts of water quality. In fact river users place a higher importance on the microbiological characteristics of the water, on the contrary passive users are more concern with appearance of the river and its biodiversity.

6. Conclusions

The water purification service offers a number of features that matters in assessment, valuation and accounting.

Firstly, in inland waters we deal with a sink service (according to typology reported in Annex I) that is characterized by:

- an absorption rate that can be exceeded - this would make the assessment of a potential flow needed in order to measure whether overuse and eventually degradation occur;
- the existence of enabling pressures that differ from final beneficiaries – this matters when considering the use of accounts in policy making, especially when dealing with specific environmental quality targets and the protection of human health.

Secondly, there can be many modelling techniques that practitioners can use. The main message is: it is more important to focus on the indicators obtained rather than on the tools to carry out the biophysical assessment. Once the indicator for the accounting in physical terms is clear, the choice of the appropriate biophysical model should account for the spatial scale, the temporal resolution, and the availability of data and expertise.

Thirdly, water purification has direct linkages with other ecosystem services, such as soil decontamination; it is strictly linked with water supply although these services risk sometime to overlap in terms of final beneficiaries. Water purification has also indirect linkages with other ecosystem services. For example, Ricketts et al. (2016) analysed the link between biodiversity and water purification, based on studies published in the literature. Moreover, for provisioning services, such as water abstractions for irrigation and crop yield from intensive farming practices (using high quantity of fertilisers and pesticides) can increase nitrogen pollution in aquatic ecosystems, requiring water purification above the capacity of the ecosystem. Similarly cultural services such as recreational bathing when too intensive can degrade the aquatic ecosystem and become a source of further pollution, demanding additional water purification. Showing all the benefits provided by ecosystem in good condition offers an argument for protecting and restoring ecosystems (Guerry et al. 2015, Burton et al. 2016) and it is of particular interest when implementing policies and management plans for protecting aquatic ecosystems, such as in the case of the Water Framework Directive in the European Union (Vlachopoulou et al. 2014).

Thirdly, valuation techniques may be very different according to what is meant to be measured:

- the water purification process;
- the benefit generated in terms on cleaned water as SNA product;
- the non-SNA benefits generated in terms of components of human wellbeing, including the human health.

It is important to be clear on the step of the accounting logic chain (Figure 5) valuation refers to. The logic chain in fact facilitates the avoidance of double counting and conceptual inconsistencies.

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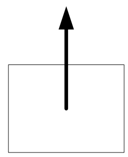
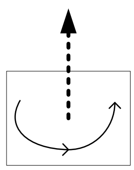
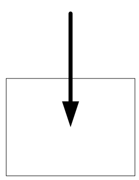
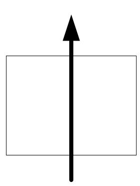
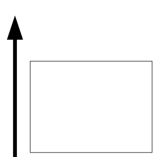
Annex I: Typologies of ES flow according to the role of ecosystems (source La Notte et al. (2019)[4])

Role of the ecosystem	Potential flow	Description
 Source: productivity	Net delivery of biomass or energy eventually leaving the ecosystem	Ecosystems act as sources of matter and energy in the form of biomass.
 Source: suitability	Delivery of biomass and energy generated within the ecosystem	Ecosystems act as sources of matter and energy by providing suitable habitats.
 Sink	Matter or energy absorbed by the ecosystem	Ecosystems act as sinks to store, immobilise or absorb matter.
 Buffer	Matter or energy flowing through the ecosystem	Ecosystems act as transformers, changing the magnitude of flows of matter or energy.
 Information	Information delivered by the ecosystem	Ecosystems deliver information. The information generated does not modify the original state of the ecosystem.

Legend:
squares represent an ecosystem unit and arrows represent the type of matter/energy/information delivered

[4] La Notte, A., Vallecillo S., Marques A., Maes J., (2019). "Beyond the economic boundaries to account for ecosystem services." Ecosystem Services 35: 116-129. Available at https://www.sciencedirect.com/science/article/pii/S2212041617307246