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Note to the Editor: Microalgae cultivation for wastewater treatment and biofuel production: a bibliographic overview of past and current trends

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Abstract

Utilization of microalgae for bioremediation of wastewaters with the concomitant production of bio-products is a recurrent subject found with increasing presence in the current scientific literature. Much of the investigative focus and research approach reported so far, give credit to the wastewater engineering roots of this research topic. Nevertheless, given the more recent increased intensity in microalgae investigations, that research is rapidly expanding to integrate wastewater engineering with multiple disciplines including cell biology and phycology research protocols among others. We present herein a keyword based analysis of trends and directions as gleaned from the body of scientific publications at the intersection of wastewater treatment and algal cultivation with a focus on the identification of past and current trends, possibly indicative of future directions.

Introduction

Research interest in the quality of receiving surface waters and in the related field of treatment of municipal and industrial wastewaters becomes discernable in the scientific literature in the late 1960's [1, 2]. These efforts coincide with the creation by US EPA of the Clean Water Act of 1972, which was designed to regulate the restoration and to uphold the quality of the water sources in the United States. Related regulations on water discharge, stimulated investigations on effective means of nutrient removal, primarily N and P, including the option of microalgae. Removal of excess Nitrogen (N) and Phosphorus (P) from discharged wastewaters mitigates eutrophication of surface waters [1]. The use of algae to treat wastewaters with the goal to minimize nutrient and BOD of treated effluents have been long considered for environmental quality reasons [1, 3]. Employing algae for treatment of wastewater with simultaneous production of biomass and biofuels is considered to be an emerging trend over the course of the past decade. Yet more significant peer reviewed literature targeting the use of [micro]algae as an option for wastewater treatment can be traced to about 1977, with a first clear statement on the value of wastewater for algal production published in 1979 [4]. Subsequently US national programs aimed at the development of algal based biofuels also integrated wastewater research elements, especially after 1980 [5, 6]. The high nutrient requirement estimates for large-scale algae biomass production, has led researchers to suggest the coupling of high nutrient wastewater treatment and algae growth [4, 5]. An added benefit of wastewater treatment by algae is the fixation of CO_2 [7-10]. Biological nutrient removal by algae in wastewater has been shown to be effective in a variety of systems including traditional ponds, high rate algal ponds and bioreactors and can be carried out by many different algal species. Combining wastewater treatment and algae biofuel production facilities, the two processes can be turned from energy sinks into a positive energy source [11]; the energy savings are directly related to the energy required for the treatment of municipal wastewater and the energy required to supply the nitrogen and phosphorus sources for algae growth. Nevertheless, any extensive literature focused on the same process but with a new application of [bio]fuel production is a rather recent phenomenon [12] that can be more obviously identified for only about 10 years, with a significant increase after 2010 [6].

Therefore, research and funding in recent years has been invested in discovering the process and benefits of creating biofuels from wastewater derived algal biomass. We used a literature survey of methodology to reveal to the apparent trends in the related research and the extent to which certain research aspects advanced.

Methodology

We reviewed publication trends as a means to understand research trends in algal biofuel production employing wastewater as growth substrates. More general, but related, areas of research such as “water” and “algae” were also investigated to offer a contextual comparison between more established fields of research and the emerging field of algae for biofuel production. Keyword queries were carried out nested, starting with an initial wide scope query followed by sub-queries, to produce wide and narrow scope datasets. For example, the results of an initial query for “wastewater” were then queried for “treatment”, with the resulting subset queried for “algae”, and eventually this subset queried for “biofuel/fuel” (Table 1).

Table 1. SCOPUS keyword queries (queries carried out for the entire period covered by SCOPUS; data extracted separately for each year)

Figure 1a	**Figure 1b**
"Water"	"Algae"
"Algae"	"Wastewater"
"Wastewater" and "Treatment"	"Wastewater" and "Treatment"
"Wastewater" and "Treatment" and "Algae"	"Wastewater" and "Treatment" and "Industrial" and "Algae"
"Biofuel"	"Wastewater" and "Treatment" and "Municipal" and "Algae"
"Biofuel" and "Ethanol"	"Wastewater" and "Treatment" and "Dairy" and "Algae"
"Biofuel" and "Biogas"	"Wastewater" and "Treatment" and "Swine" and "Algae"
"Biofuel" and "Biodiesel"	"Wastewater" and "Treatment" and "Industrial" and "Algae" and "(Bio)fuel"
"Biofuel" and "Algae"	"Wastewater" and "Treatment" and "Municipal" and "Algae" and "(Bio)fuel"
"Wastewater" and "Treatment" and "Algae" and "Biofuel"	"Wastewater" and "Treatment" and "Dairy" and "Algae" and "(Bio)fuel"
	"Wastewater" and "Treatment" and "Swine" and "Algae" and "(Bio)fuel"
Figures 2 and 4	**Figure 3**
"Wastewater" and "Treatment"	"Wastewater" and "Treatment"
"Wastewater" and "Treatment" and "Algae"	
"Wastewater" and "Treatment" and "Algae" and "(Bio)fuel"	

A comparison of WOS (webofscience.com) and SCOPUS (scopus.com) searches indicated similar trends. SCOPUS however has a larger coverage and consistently produced larger datasets. Consequently, analyses presented here are based on SCOPUS search results. Results include all publication types covered by SCOPUS, not only journal articles but also conference proceedings, books and book chapters, trade publications, and reports; this offers a better description of the research activities especially for emerging fields.

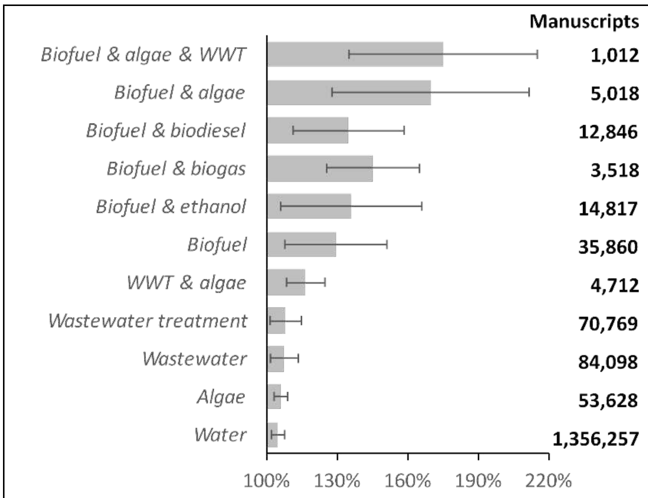
The periods covered continuously in the datasets obtained by different queries varied. Queries for "wastewater treatment" (wwt) recovered publications for the period from 1970 to 2015, the subset for the "wastewater treatment" and "algae" (wwt/a) recovered publications for the period from 1977 to 2015, while the query for "wastewater treatment" and "algae" and "(bio)fuel" (wwt/a/bf) only recovered any relevant publications for the period between 2006 and 2015. These variations in query coverage reflect the historical length of the publication record as identified via SCOPUS. The publications for the current year, 2016, yet to be finalized, were not included in the analysis. Keyword queries (Table 1) were carried out in the "title", "abstract" and "keywords" sections of the publication as parsed by SCOPUS. Eventually, keywords associated with each year for each query were summarized. This produced a total of 2402 keywords. These keywords were first normalized for grammatical and spelling variations, and then the keywords dataset was further reduced by eliminating redundancies due to words with similar meaning. All these modifications were replaced in the original datasets. Eventually a reduced dataset included 552 unique keywords. After eliminating general terms that would have biased any subsequent dissimilarity analysis (e.g., "algae" or "fuel"), the dataset was further reduced to 539 unique keywords; of these wwt query included 270 keywords, wwt/a 419 keywords, and wwt/a/bf 202 keywords. Of these 49 keywords were found only in the wwt dataset, 169 only in the wwt/a dataset and 58 only in the wwt/a/bf dataset; 103 keywords were common for all three datasets. Variable counts of these keywords – i.e., abundance – were found in each datasets; to normalize their usage intensity the abundance of each keyword for a given query and year was divided by the respective publication counts. Subsequent analyses were thus carried out on these keywords intensity datasets. Statistical analyses were carried out mainly in PAST3.0 [13]. All errors reported here describe the statistical 95% confidence interval.

To estimate the intensity of research for the different research areas the publication records were compared to the publication records for "water" as returned by SCOPUS.

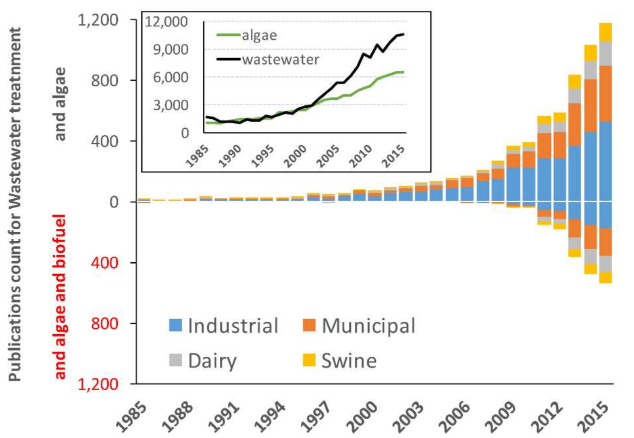
Results and Discussion

Publication rates

The annualized rate of increase in publication counts can be used as an indication of the maturity of the respective field. Figure 1 summarizes these rates from 2006 to 2015, the period with publications in wwt/a/bf area. A mature research area, such as water or algal research, while producing a large number of publications it does have a proportionally low publication rate increase. It is interesting to note that the use of algae for wastewater treatment also behaves like a relatively mature field despite the comparatively smaller publication count (Figure 1a).



a. *Publications; average annual increase rate and total (2006-2015)*



b. *Publications related to algae and biofuels across wastewater types*

Figure 1. Publications for selected research areas (SCOPUS search results; error bars are 95% Confidence Intervals); Manuscript counts sum the period from 2006 through 2015

On the other hand, the usage of algae for the production of biofuel, with or without wastewaters, is a new and growing field. This is confirmed by the similar trend in publishing between wwt/a and wwt/a/bf (Figure 1b); note that wwt/a/bf is a 20% subset of wwt/a. Moreover, the similarity carries into the type of wastewater researched; for both treatment and biofuel production, municipal, industrial, and farm wastewater streams are considered.

Keyword utilization patterns

Variable intensity in the keywords utilization can be used to infer the attention to the associated research areas. Initial interest in the wastewater treatment was obviously driven by environmental concerns (Figure 2), with proportionally less direct interest in the nutritional component of wastewaters. More recently, nutrients and nutrient removal became of greater interest for the research community, at the same time as bioreactor based research increased. It is interesting to note the spike in nutrient removal research, around 2010, that coincides with the more significant accumulation of wwt/a/bf research. Modeling, an indication of an interest for engineered management of wastewater systems, was a relative constant from 1970 on; nevertheless, the last 10 years, when wwt/a/bf research surged, an accompanying interest in modeling waned. This might be attributed to the novelty of this research and thus to the fact that much research is still descriptive in nature and has yet to mature and move into the development of coherent management tools.

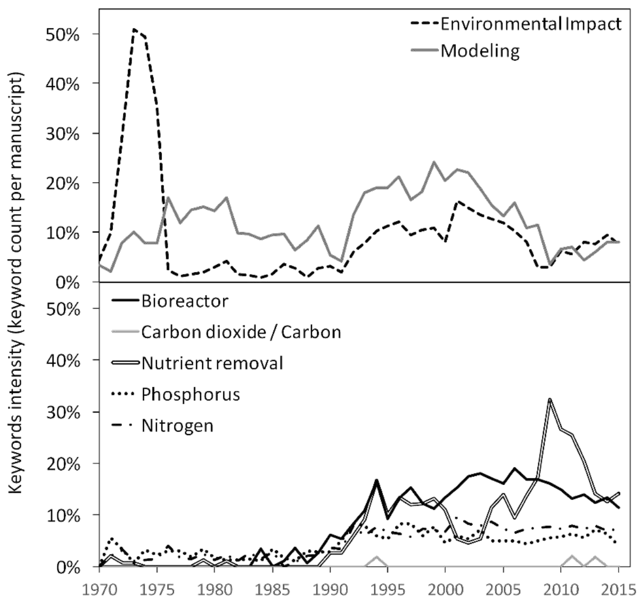


Figure 2. Selected keyword utilization rates for the “wastewater treatment” query

Keyword intensity, described as the proportional count of a keyword per articles, reflects the main foci of research in a given area.

It is quite obvious that wwt research was initially driven by concerns regarding the environment. Thus, for the 1972-1973 environmental impact keywords were identified in about 50% of related publications (Fig. 2). This was followed by a sustained increase in modeling efforts, likely summarizing the extensive modeling of wastewater treatment carried out by the profession of Civil Engineering [2]. A simple look at the most dominant keyword for the three datasets, for the period after 2000, shows “modeling” to dominate the wwt publications (11.5%), “management” and “water pollutants/pollution” closely linked for the wwt/a publications (20.1% and 19.0%, respectively), and “biomass”, at 72.8%, clearly dominating the ww/a/bf publications. It is noteworthy that the pollution focus of the wwt/a publications is also associated with a significantly stronger focus on metal and toxicity terminology (see Supplementary table 2); average abundance for the keywords subset including As, Cd, Cr, Cu, Ni, Zn, “metals” and “metal ions” was 1.36%±0.69% for wwt and 4.39±1.66% for wwt/a; none were found in the wwt/a/bf publications dataset. This strengthens the conclusion that addition of algae to the wastewater treatment technologies was carried out with the goal of treating and not to obtain algal bio-products.

It is interesting to note the sustained, simultaneous, increase of both environmental impact and modeling research in the 1990-2010 period (Fig. 2). As the interest in utilization of wastewater for algal biofuel peaked after 2010, the general intensity shifted away from environmental impact and modeling to focus on nutrient removal (Fig. 2).

The interest in wastewater and algae can be followed by identifying the increased intensity of bioreactor type keywords (Fig 2a). This coincides with the conclusion of the first concerted effort to evaluate the utility of algae for energy production [5]. The intensity of research on N and P follows a similar trend. It is therefore of interest to note the peak of "nutrient removal" just around 2010, in the middle of the second revival of interest in wastewater and algae for biofuel [6]. Moreover, this also indicates that the dominant paradigm in wastewater and algae for biofuel research hovers around the capacity of algae to remove nutrients from wastewaters, not necessarily the capacity of wastewater to support algal growth. It might be argued that this is just a continuation of earlier efforts to use algae for wastewater treatment, a carry-over of this research into new exploratory research evaluating a range of wastewater for algal growth; the latter would be expected to be integrated and reflected into growth modeling research, when and if an industrial management system for algal bio-products produced on wastewater is considered for managed production conditions.

Wastewater treatment aims to lower BOD and remove nutrients to eventually minimize eutrophication risks in receiving waters [3]. On the other hand, it might be envisioned that if wastewaters are to be primarily employed for growth of algae and production of algal biomass then the availability of nutrients to algae ought to take priority. A high density of "nutrient removal" ("nr") is expected to support the former paradigm; a high density of "nutrient availability" ("na") or "nutrient uptake" ("nu") would support the later paradigm. Keyword abundance data for the after 2000 datasets supports the dominant use of "nr" (28.1% for wwt/a, and 17.5% for wwt/a/b) when algae and wastewater are concerned over the use of "na" and "nu", 0.97% and respectively 0.78% for the wwt/a/bf; the latter two terms are not present in the wwt dataset (Suppl. Table 2). This supports the conclusion that while the concept of algae employing wastewater as a source of nutrients starts to make inroads in the literature the main approach is, still, to use algae as removers of nutrients. The increasing use of "nutrient" for the wwt/a/bf literature (18.87%, versus 1.75% for wwt, and 9.38% for wwt/a) also indicates a shift in the approach, but its direction more difficult to gage without a qualifier term.

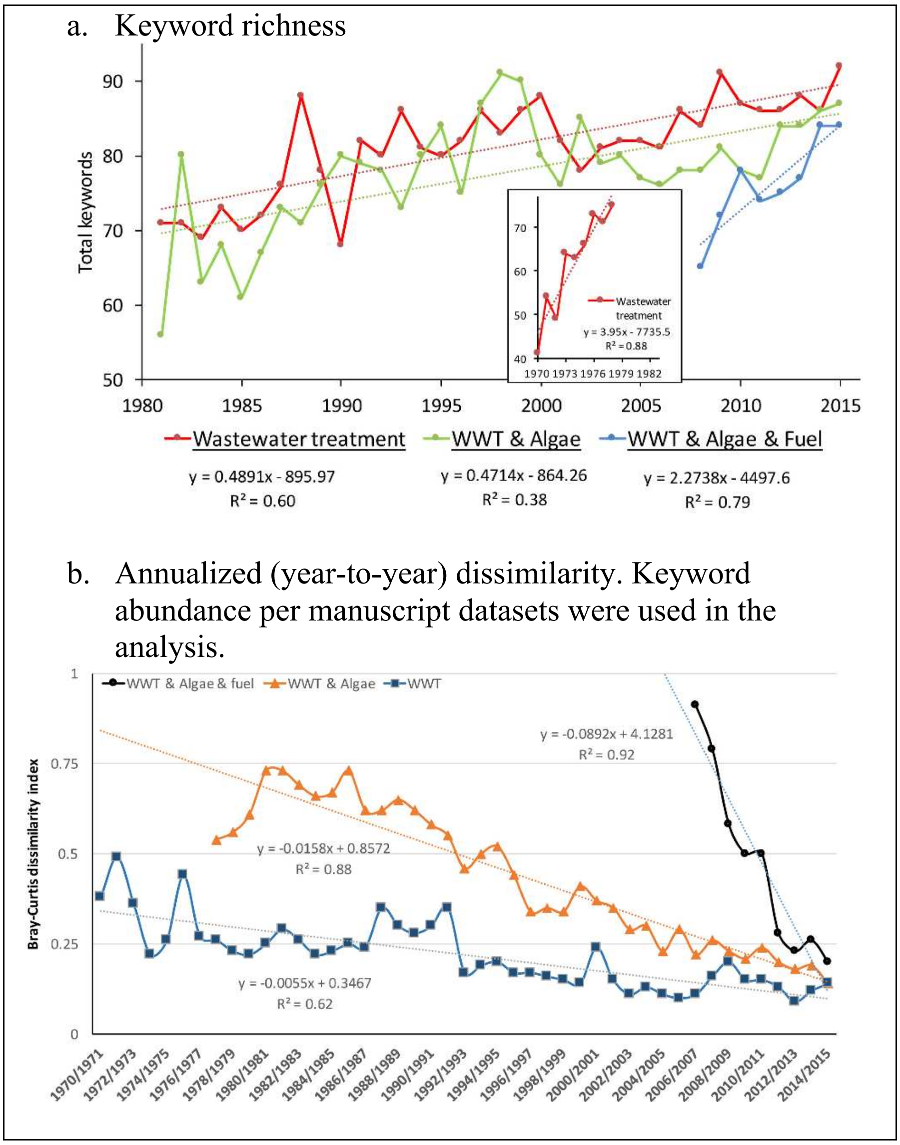


Figure 3 Temporal shifts in keyword utilization

Keyword utilization patterns

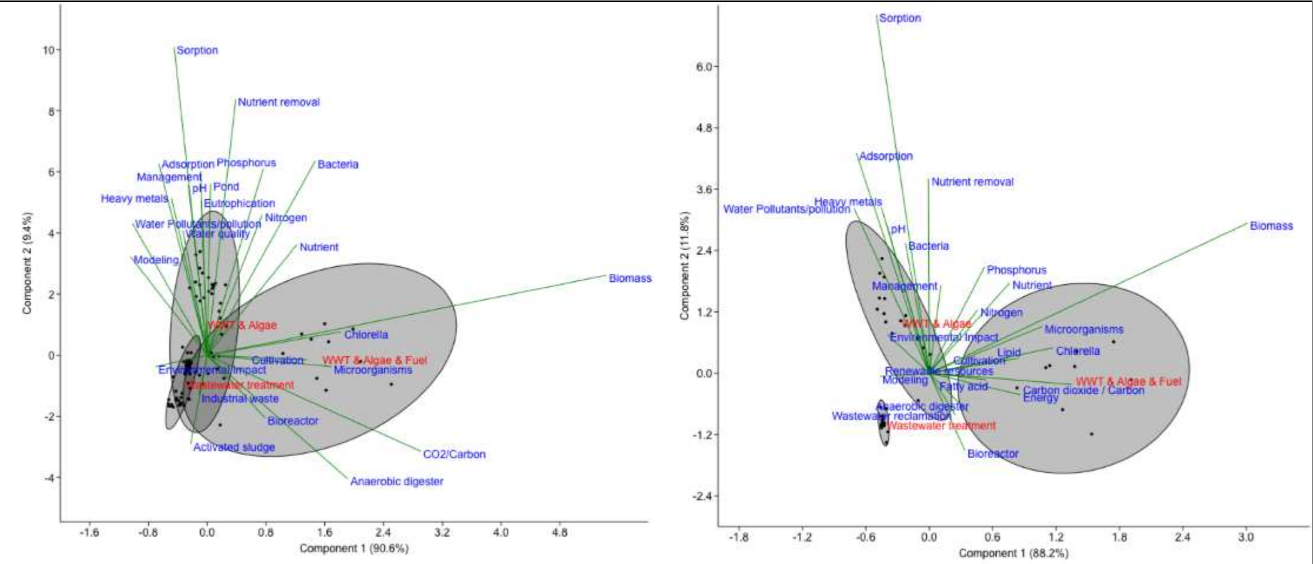
Keyword richness increases as the scope of a given research field expands. All three areas of research show an increased in keyword richness to reach a somewhat similar richness in 2015 (Figure 3a). For the more established wwt and wwt/a research areas there is an average annual increase of about 0.5 keywords y^{-1}. On the other hand, wwt/a/bf has shown a rapid increase of 2.3 keywords y^{-1}, consistent with a rapidly expanding research field; this pattern is consistent with the early stages of a newly establishing field as shown by the similar rapid increase of 3.95 keywords y^{-1} in the early years of wwt research. There is an obvious reset in the keyword richness for wwt and wwt/a around year 2000; this is what prompted the dataset split in our evaluation to also include an only after 2000 data analysis.

Another indicator of a maturing research field is the stabilization of the range of inquiry. As the range expands proportional changes in the coverage over time normalizes, tending towards a steady state situation, one can assume, for a field that shifts from discovery to applications. We employed a Bray-Curtis dissimilarity index analysis to assess the year-over-year changes in similarity between the annual keyword datasets, i.e. the running dissimilarity (Figure 3b). Bray-Curtis considers both presence and abundance for the similarity calculation. For all fields the running Bray-Curtis index declines with time, more accelerated for the faster maturing fields.

Values of dissimilarity above the long term average trend (i.e. the linear fit line) indicate either a slower decrease in dissimilarity or even an increase in dissimilarity for the pair of years in comparison to the previous period of time. This would be expected to occur when the set of newly added keywords are significantly different from the previous year's keyword, thus an indication of an increase in the scope of research in the respective area, or in other words a more innovative period.

On the other hand, dissimilarities lower than the multiannual trend would indicate a relative stagnation in the scope of research, or a more stable, less innovative, research activity. For all three research areas evaluated here there is a consistent decrease trend in year-over-year dissimilarity values. It may be assumed that this is a reflection of a stabilization of the research foci.

A principal component analysis, carried out for the top 25 drivers of dissimilarity, according to a SIMPER analysis (Table 2 and 3) indicates a shift in the more recent period. While when the entire dataset is employed the dissimilarity among datasets is not statistically significant at an alpha of 0.05. The analysis confirms the shift from water quality and pollution issues towards biomass production parameters. *Chlorella* sp. is the preferred organism. The utilization of algae for heavy metal remediation is again confirmed as a strong research focus during earlier wastewater and algae research (Fig 4 a and b) which all disappeared from the dataset that has a biofuel focus.



a. From 1970 to 2015 **b.** From 2000 to 2015

Figure 4. Principal Component Analysis (PCA) for the top 25 discriminant keywords (Table 2 and 3) for two distinct time periods; keyword intensity datasets were employed in the analysis (i.e. for each year and category keywords abundance was divided to the number of manuscripts). PCA was carried out in Past3.07, employing Bray-Curtis dissimilarity algorithm. The grey ellipses encompass the 95% confidence region.

Table 2 Top 25 keywords inducing dissimilarities between publication datasets for years 2000 to 2015 (SIMPER analysis with Bray-Curtis distance, [13])

Keyword	Dissimilarity		Mean Abundance (%)		
	Average	Contribution %	wwt (2000-2015)	wwt/a (2000-2015)	wwt/a/bf (2006-2015)
Biomass	3.11	5.04	5.30	21.3	72.8
Sorption	1.43	2.32	1.10	24.6	0.00
Water Pollutants/pollution	1.25	2.03	19.0	28.9	5.90
CO_2/Carbon	1.25	2.02	0.20	2.00	34.9
Adsorption	1.22	1.97	9.70	23.4	0.00
Nutrient removal	1.20	1.95	14.8	28.1	16.7
Bacteria	1.13	1.83	16.4	24.8	30.4
Microorganisms	1.09	1.76	2.60	7.80	23.8
Chlorella	1.05	1.70	0.00	4.00	23.2
Nutrient	0.99	1.60	1.80	9.40	18.3
Management	0.98	1.59	20.1	26.3	20.7
pH	0.87	1.41	11.5	20.8	5.40
Heavy metals	0.85	1.38	6.00	16.4	0.20
Phosphorus	0.83	1.34	5.40	13.6	17.0
Cultivation	0.81	1.32	0.00	2.30	17.1
Lipid	0.80	1.29	0.00	2.60	16.6
Anaerobic digester	0.79	1.28	4.20	2.20	25.5
Energy	0.76	1.24	0.00	0.20	18.3
Modeling	0.74	1.20	11.5	10.4	0.40
Fatty acid	0.73	1.18	0.00	0.60	23.8
Nitrogen	0.71	1.16	7.60	12.8	16.5
Renewable resources	0.65	1.05	0.10	0.60	19.2
Bioreactor	0.63	1.02	14.9	10.3	16.8
Wastewater reclamation	0.63	1.02	7.10	4.70	9.60
Environmental Impact	0.62	1.00	8.70	10.6	0.40
Total	25.12	40.68			

Table 3. Top 25 Keywords inducing dissimilarities between publication datasets for years 1970 to 2015 (SIMPER analysis, [13])

Keyword	Dissimilarity		Mean Abundance (%)		
	Average	Contribution %	wwt (1970-2015)	wwt/a (1977-2015)	wwt/a/bf (2006-2015)
Biomass	2.84	4.00	3.40	17.8	72.8
Nutrient removal	1.64	2.30	7.60	19.9	16.7
Bacteria	1.63	2.30	8.70	20.4	30.4
Management	1.59	2.23	18.8	26.9	20.7
Water Pollutants/pollution	1.28	1.80	16.4	20.4	5.90
Phosphorus	1.13	1.59	4.30	14.3	17.0
Sorption	1.08	1.52	0.50	13.5	0.00
Modeling	1.06	1.49	11.9	14.2	0.40
Nutrient	1.04	1.46	1.20	8.60	18.3
pH	1.04	1.46	5.80	12.9	5.40
Nitrogen	1.02	1.44	4.80	12.7	16.5
Adsorption	1.02	1.43	5.10	12.4	0.00
Microorganisms	0.93	1.31	2.80	5.60	23.8
Chlorella	0.91	1.28	0.00	4.70	23.2
Environmental Impact	0.89	1.25	9.30	7.40	0.40
Bioreactor	0.87	1.22	7.90	6.70	16.8
CO_2/Carbon	0.87	1.22	0.10	1.60	34.9
Industrial waste	0.77	1.09	9.40	7.30	7.30
Heavy metals	0.74	1.04	3.70	9.80	0.20
Pond	0.70	0.99	0.20	8.00	3.60
Anaerobic digester	0.70	0.98	3.60	1.80	25.5
Water quality	0.68	0.96	5.50	10.5	3.40
Cultivation	0.68	0.95	0.10	2.60	17.1
Activated sludge	0.66	0.92	9.10	4.70	4.80
Eutrophication	0.63	0.88	0.10	7.00	1.70
Total	26.4	37.11			

Table 4. Statistical analysis of parameters for keyword induced dissimilarities among the publication datasets

Publications dataset	Dissimilarity		Proportional dissimilarity (%)		Keyword abundance (%)[3]	
	SUM[1]	MAD[2]	SUM	MAD[2]	Mean±CI_{95}	Median±MAD[2]
After 1970						
wwt	7.41	0.05	12.01	0.08	2.04±0.62	1.07±0.69
wwt/a	21.06	0.14	34.12	0.23	5.37±1.58	2.74±2.16
wwt/a/bf	32.84	0.14	53.21	0.23	7.84±1.92	4.76±3.75
After 2000						
wwt	8.96	0.06	12.60	0.09	1.50±0.55	0.66±0.58
wwt/a	28.74	0.04	40.39	0.06	2.08±0.60	0.53±0.37
wwt/a/bf	33.44	0.09	47.01	0.13	6.30±1.54	2.72±2.25

[1] SUM, sum of the SIMPER calculated dissimilarity
[2] MAD, median absolute deviation
[3] Keyword occurrence per peer reviewed publication (from 0 to 100%).

The shift away of wwt/a/bf from wwt and wwt/a can be seen in the 53.21% total impact on dissimilarity of the keywords that were most dominant in wwt/a/bf. Both standard and robust statistical tests indicate a more concentrated focus for the wwt/a/bf publications (Table 4).

Review of reviews

In 1978 the Aquatic Species Program [5], an US national funded effort, also identified possibilities for producing biofuels through algae and microalgae cultivation. In 1979 Beneman et al. [4] published a conceptual map for the use of wastewater for the culturing algae on wastewaters for fuel production. Much of the initial efforts were focused on hydrogen production with biodiesel becoming a primary focus only after 1980. The program was terminated in 1996. In 2010, a new algae for biofuel program was established [6] that included again a focus on 'Integration with water treatment facilities". A summary of the relevant review articles might be expected to offer as a reasonable guide to the scope and the evolution of the state of the art knowledge in a given area of research. As described above, about 78 review publications were identified to focus on wastewater, algae and energy issues. A query, for reviews with the keywords "algae" (including "microalgae" and different spellings) and "wastewater" produced a dataset of 230 reviews. These reviews were examined and only the ones focusing on growth of algae in wastewater were retained. Reviews focused on the impacts of wastewaters on environment and on algal blooms in water bodies, and general wastewater treatment or biosorption reviews were excluded of this work. Eventually 78 reviews were identified as relevant to our interest in biofules from algal biomass cultivated in wastewater (as listed by SCOPUS on March 16, 2016). The bulk of reviews, many with a (bio)fuel perspective were published after 2010. Generally, the parameters affecting algae production in wastewater have been extensively reviewed with an engineering perspective.

The first identified review about the growth of algae in wastewater, from a biotechnology perspective, was published in 1997 [14]. The authors discussed the use of microalgae for bio-treatment and by-products with an emphasis on *Chlamydomonas reinhardtii*. The mass culture was already a matter of concern and the advantages of immobilization technique were also presented. Most reviews focused on the production of algae with a large majority included harvesting [7, 9, 10, 15-40] with two of them dedicated exclusively to harvest issues [41, 42]. Biodiesel production was the focus of several reviews, especially after 2010 [16, 21, 33].The role of the light source as a specific topic for cultures in bioreactors was evaluated by two reviews, also after 2010, but not necessarily for wastewater based systems [43, 44].

A large number of reviews focused on system conceptualization with a focus on defining a bio refinery strategy [7, 9, 14, 16-20, 22, 23, 27-31, 37-39, 42, 45-54]. Makrou et al. highlighted the carbohydrate production as a specific product for biofuel production [55].

Very recently, after 2014, a number of somewhat similar reviews focused on algal biofilms for wastewater systems and biofuel production [56-58] an indication of the speed at which the field advances, and likely the tight competition among research groups. Genetic engineering is also touched by some of these reviews [16, 19, 21-24, 28, 29, 47, 52, 59, 60].

Impacts of large-scale cultures on environmental governance [61], environment [62, 63], resources (specific to China;[64]) and cost [63, 65] have also been analyzed. In most cases, there was no new exploration for algal biodiversity [59]. Alga species from the genus *Chlorella* remain dominant for algal growth and the exclusive focus for two reviews from 2013 and 2015 [49, 54]. While many studies on algal growth have been performed with artificial media a range of wastewaters have also been investigated [64]. It is encouraging that a more biological view, with elements of management are also considered by reviews summarizing the interactions among algae [66, 67], with microbial consortia [15, 34, 46, 49], and especially with wastewater associated microbes [68, 69]. Consortia of microalgae, as opposed to single species cultures, are shown to be advantageous for productivity and crop stability [67, 70]. A few of the recent reviews advocate for mixotrophic cultivation as a means to enhance biomass productivity [52, 53, 70, 71], while the two-stage cultivation, with a luxury consumption stage followed by nitrogen limitation, is recommended for lipid production [58, 70, 71]. Both nutrient removal [72-75] and nutrient uptake [32, 76, 77] are discussed in the context of lipid production.

Conclusions

Growing algae for biofuel on wastewater substrates is a rapidly growing area of research, with a comprehensive approach expanding outside the usual scientific disciplines commonly associated with wastewater treatment, even when algae are included as a treatment option. On the other hand, while the concept is several decades old, the relative rapid expansion led to a large number of exploratory research initiatives, with minimal focus on integrated bioengineering management protocols. We may therefore assume that we are likely in the data accumulation stage that will offer, hopefully soon, a sufficient basis for a strong shift of research into the development of management systems. Many other factors beyond the scope of the strict scientific endeavors will likely be decisive for such shift. Nevertheless, a focused global approach is clearly of benefit for a successful translation of current understanding into sustainable practice.

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Supplementary data:

Supplementary Table 1: Keywords inducing dissimilarities between publication datasets for years 2000 to 2015 (SIMPER analysis,[13]); SIMPER analysis was carried out on keyword intensity datasets.

	Keyword (2000 to 2015)	Dataset where keyword is dominant	Dissimilarity		Mean abundance (%)		
			Average	Contribution (%)	wwt (2000-2015)	wwt/a (2000-2015)	wwt/a/bf (2006-2015)
1	Modeling	wwt	0.74	1.20	11.50	10.40	0.42
2	Activated sludge	wwt	0.50	0.81	9.56	4.54	4.79
3	Oxidation	wwt	0.45	0.74	6.68	3.57	2.27
4	Membrane bioreactor	wwt	0.36	0.59	4.91	0.11	1.75
5	Sludge	wwt	0.31	0.50	5.44	1.66	0.42
6	Water supply	wwt	0.29	0.48	5.15	2.85	1.94
7	Filtration	wwt	0.29	0.47	4.90	2.93	0.83
8	Phenols	wwt	0.27	0.44	4.23	0.00	0.00
9	Biofilm	wwt	0.27	0.43	3.71	2.11	2.72
10	Water management	wwt	0.26	0.43	4.28	3.69	1.90
11	Denitrification	wwt	0.25	0.40	4.22	1.01	0.00
12	Nitrification	wwt	0.22	0.36	3.77	0.96	0.29
13	Reaction Kinetics	wwt	0.22	0.35	3.30	3.24	0.00
14	Optimization	wwt	0.19	0.31	2.78	0.76	1.93
15	Oxidation-Reduction	wwt	0.17	0.28	2.69	0.48	0.00
16	Coagulation	wwt	0.16	0.25	2.07	0.70	1.11
17	Groundwater	wwt	0.15	0.25	2.42	0.20	0.00
18	Iron	wwt	0.15	0.25	2.36	1.36	0.00
19	Catalysis	wwt	0.13	0.22	1.74	0.00	0.83
20	Isolation and purification	wwt	0.13	0.21	1.04	0.91	1.01
21	Microbial activity	wwt	0.11	0.18	1.07	0.92	0.47
22	Mass spectrometry	wwt	0.10	0.17	1.61	0.14	0.00
23	Microbial community	wwt	0.10	0.16	1.06	0.48	0.64
24	Water sampling	wwt	0.10	0.16	1.18	0.74	0.00
25	Irrigation	wwt	0.10	0.16	1.46	0.20	0.00
26	Contamination	wwt	0.09	0.14	1.09	0.57	0.00
27	Wastewater disposal	wwt	0.07	0.12	1.07	0.19	0.00
28	Soil	wwt	0.07	0.12	1.07	0.20	0.00
29	Aeration	wwt	0.07	0.12	0.95	0.00	0.38
30	Hydrogen peroxide	wwt	0.07	0.12	1.14	0.00	0.00
31	Ozonation	wwt	0.07	0.11	1.09	0.00	0.00
32	Ultraviolet radiation	wwt	0.07	0.11	0.98	0.19	0.00
33	*Gadus morhua*	wwt	0.07	0.11	0.97	0.19	0.00
34	Waste disposal	wwt	0.06	0.10	0.74	0.37	0.00
35	Photocatalysis	wwt	0.06	0.10	0.92	0.00	0.00
36	Ultrafiltration	wwt	0.06	0.09	0.86	0.00	0.00
37	Escherichia coli	wwt	0.05	0.08	0.57	0.30	0.00
38	Engineering	wwt	0.05	0.08	0.67	0.22	0.00
39	X ray diffraction	wwt	0.05	0.08	0.71	0.00	0.00
40	Titanium dioxide	wwt	0.05	0.08	0.71	0.00	0.00

	Keyword (2000 to 2015)	Dataset where keyword is dominant	Dissimilarity		Mean abundance (%)		
			Average	Contribution (%)	wwt (2000-2015)	wwt/a (2000-2015)	wwt/a/bf (2006-2015)
41	Wastewater, textile mills	wwt	0.04	0.07	0.59	0.18	0.00
42	Reactors	wwt	0.04	0.07	0.69	0.00	0.00
43	Acids	wwt	0.04	0.07	0.48	0.29	0.00
44	Drinking water	wwt	0.04	0.07	0.38	0.36	0.00
45	Nanoparticles	wwt	0.04	0.06	0.30	0.16	0.21
46	Chlorine/chloride	wwt	0.03	0.05	0.51	0.00	0.00
47	Fouling	wwt	0.03	0.05	0.31	0.16	0.00
48	Wastewater, papermill	wwt	0.03	0.04	0.40	0.00	0.00
49	Anaerobic metabolism	wwt	0.02	0.04	0.26	0.16	0.00
50	Sequencing Batch reactors	wwt	0.02	0.03	0.30	0.00	0.00
51	Liquid chromatography	wwt	0.02	0.03	0.23	0.00	0.00
52	Photodegradation	wwt	0.01	0.02	0.23	0.00	0.00
53	Chromatography	wwt	0.01	0.02	0.23	0.00	0.00
54	Aromatic compounds	wwt	0.01	0.02	0.21	0.00	0.00
55	Transmission electron microscopy	wwt	0.01	0.02	0.19	0.00	0.00
56	Sorption	wwt/a	1.43	2.32	1.10	24.60	0.00
57	(Waste) Nutrient removal	wwt/a	1.26	2.04	15.30	28.10	17.53
58	Water Pollutants/pollution	wwt/a	1.25	2.03	19.00	28.90	5.89
59	Adsorption	wwt/a	1.22	1.97	9.70	23.40	0.00
60	Management	wwt/a	0.98	1.59	20.10	26.30	20.70
61	pH	wwt/a	0.87	1.41	11.50	20.80	5.36
62	Heavy metals	wwt/a	0.85	1.38	5.97	16.40	0.21
63	Environmental Impact	wwt/a	0.62	1.00	8.66	10.60	0.35
64	Industrial waste	wwt/a	0.59	0.95	7.88	10.00	7.28
65	Water Purification	wwt/a	0.53	0.85	8.02	11.70	7.02
66	Isotherms	wwt/a	0.49	0.79	0.24	8.17	0.00
67	Biodegradation	wwt/a	0.44	0.72	10.50	12.50	6.90
68	Water quality	wwt/a	0.43	0.69	7.74	11.30	3.44
69	Oxygen demand	wwt/a	0.41	0.66	5.53	5.95	4.82
70	Pollutants/pollution	wwt/a	0.40	0.65	5.43	6.23	5.41
71	Chromium	wwt/a	0.39	0.63	2.32	6.90	0.00
72	Eutrophication	wwt/a	0.38	0.61	0.00	6.27	1.66
73	Kinetics	wwt/a	0.38	0.61	4.51	8.22	0.78
74	Bioremediation	wwt/a	0.37	0.60	2.66	6.84	6.23
75	Copper	wwt/a	0.36	0.59	2.82	7.09	0.00
76	Toxicity	wwt/a	0.36	0.59	3.13	7.36	0.98
77	Cadmium	wwt/a	0.36	0.59	1.38	6.61	0.00
78	Pond	wwt/a	0.35	0.57	0.00	4.60	3.60
79	Dyes	wwt/a	0.35	0.56	4.47	4.81	0.83
80	Microbiology	wwt/a	0.31	0.50	4.42	4.46	3.14
81	Drug	wwt/a	0.28	0.45	3.69	3.73	0.96
82	Ammonia(um)	wwt/a	0.27	0.44	5.32	6.39	4.75
83	Stabilization Pond	wwt/a	0.27	0.43	0.09	4.56	0.00
84	Temperature	wwt/a	0.26	0.42	4.00	6.32	3.10
85	Rivers	wwt/a	0.25	0.40	2.38	3.47	0.70
86	Zinc	wwt/a	0.24	0.39	2.18	4.61	0.00
87	Wetlands	wwt/a	0.23	0.37	1.05	1.64	0.00
88	Metals	wwt/a	0.23	0.37	0.94	3.83	0.00
89	Ecosystems	wwt/a	0.22	0.35	0.44	3.62	0.00
90	Toxicity testing	wwt/a	0.20	0.33	0.00	3.55	0.00
91	Thermodynamics	wwt/a	0.19	0.31	0.12	3.08	0.00
92	Metals ion	wwt/a	0.18	0.30	0.86	2.85	0.00
93	Nickel	wwt/a	0.18	0.29	0.39	2.98	0.00
94	Activated Carbon	wwt/a	0.17	0.28	2.36	2.63	0.00
95	Wastewater, industrial	wwt/a	0.17	0.27	1.77	2.18	0.00
96	Organic matter	wwt/a	0.17	0.27	2.25	2.40	0.00
97	Bioaccumulation	wwt/a	0.17	0.27	0.00	2.61	0.38
98	Scanning electron microscopy	wwt/a	0.17	0.27	1.51	1.99	0.00
99	Water contamination	wwt/a	0.16	0.25	1.63	2.09	0.00
100	Dissolved Oxygen demand	wwt/a	0.12	0.19	0.67	1.58	0.29
101	Bioassay	wwt/a	0.11	0.18	0.00	2.00	0.00
102	Risk assessment	wwt/a	0.11	0.18	0.31	1.69	0.00
103	Surface waters	wwt/a	0.11	0.18	0.42	1.62	0.00
104	Disinfection	wwt/a	0.10	0.16	0.46	0.85	0.83

	Keyword (2000 to 2015)	Dataset where keyword is dominant	Dissimilarity		Mean abundance (%)		
			Average	Contribution (%)	wwt (2000-2015)	wwt/a (2000-2015)	wwt/a/bf (2006-2015)
105	Infrared spectroscopy	wwt/a	0.10	0.15	0.11	1.52	0.00
106	Fresh Water	wwt/a	0.09	0.14	0.00	0.99	0.93
107	Performance assessment	wwt/a	0.08	0.14	0.49	1.10	0.00
108	*Lemna*	wwt/a	0.08	0.13	0.00	1.36	0.00
109	*Daphnia*	wwt/a	0.07	0.11	0.00	1.17	0.00
110	Ecotoxicology	wwt/a	0.07	0.11	0.00	1.11	0.00
111	Absorption	wwt/a	0.06	0.09	0.00	0.97	0.00
112	Animal	wwt/a	0.05	0.09	0.10	0.60	0.35
113	Fisheries	wwt/a	0.05	0.08	0.00	0.89	0.00
114	Fourier transform infrared spectroscopy	wwt/a	0.05	0.08	0.24	0.59	0.00
115	Immobilization	wwt/a	0.05	0.07	0.00	0.77	0.00
116	Toxic materials	wwt/a	0.04	0.07	0.00	0.74	0.00
117	Precipitation	wwt/a	0.04	0.07	0.22	0.48	0.00
118	Dewatering	wwt/a	0.04	0.06	0.13	0.39	0.29
119	Lagoons	wwt/a	0.03	0.05	0.00	0.58	0.00
120	Calcium	wwt/a	0.03	0.05	0.14	0.44	0.00
121	Marine environment	wwt/a	0.03	0.05	0.00	0.55	0.00
122	Liquid-solid separation	wwt/a	0.03	0.04	0.12	0.35	0.00
123	Macrophyte	wwt/a	0.03	0.04	0.00	0.47	0.00
124	Turbidity	wwt/a	0.03	0.04	0.00	0.47	0.00
125	Seawater weed	wwt/a	0.02	0.04	0.00	0.46	0.00
126	Acidity	wwt/a	0.02	0.04	0.00	0.41	0.00
127	Zooplankton	wwt/a	0.02	0.04	0.00	0.41	0.00
128	Antibiotics	wwt/a	0.02	0.03	0.13	0.16	0.00
129	Arsenic	wwt/a	0.02	0.03	0.00	0.28	0.00
130	Biomass	wwt/a/bf	3.11	5.04	5.33	21.30	72.80
131	CO2/carbon	wwt/a/bf	1.25	2.02	0.23	2.02	34.90
132	Bacteria	wwt/a/bf	1.13	1.83	16.40	24.80	30.40
133	Microorganisms	wwt/a/bf	1.09	1.76	2.57	7.79	23.80
134	*Chlorella*	wwt/a/bf	1.05	1.70	0.00	3.96	23.20
135	Nutrient	wwt/a/bf	0.99	1.60	1.75	9.38	18.30
136	Phosphorus	wwt/a/bf	0.83	1.34	5.35	13.60	17.00
137	Cultivation	wwt/a/bf	0.81	1.32	0.00	2.34	17.10
138	Lipid	wwt/a/bf	0.80	1.29	0.00	2.62	16.60
139	Anaerobic digester	wwt/a/bf	0.79	1.28	4.19	2.24	25.50
140	Energy	wwt/a/bf	0.76	1.24	0.00	0.16	18.30
141	Fatty acid	wwt/a/bf	0.73	1.18	0.00	0.56	23.80
142	Nitrogen	wwt/a/bf	0.71	1.16	7.55	12.80	16.50
143	Renewable resources	wwt/a/bf	0.65	1.05	0.13	0.65	19.20
144	Bioreactor	wwt/a/bf	0.63	1.02	14.90	10.30	16.80
145	Wastewater reclamation	wwt/a/bf	0.63	1.02	7.12	4.73	9.56
146	Electricity	wwt/a/bf	0.62	1.00	0.00	0.00	15.20
147	Photobioreactor	wwt/a/bf	0.56	0.90	0.00	1.30	11.90
148	Energy production	wwt/a/bf	0.54	0.88	0.00	0.00	18.90
149	*Cyanobacteria*	wwt/a/bf	0.52	0.84	0.00	6.37	6.82
150	Growth rate	wwt/a/bf	0.52	0.83	0.00	3.38	9.57
151	Photosynthesis	wwt/a/bf	0.51	0.82	0.00	3.32	12.70
152	Biotechnology	wwt/a/bf	0.50	0.81	0.68	3.71	10.20
153	Chlorophyll	wwt/a/bf	0.49	0.80	0.00	6.09	7.28
154	Metabolism	wwt/a/bf	0.48	0.79	3.11	4.70	12.30
155	Ethanol	wwt/a/bf	0.48	0.77	0.00	0.00	15.30
156	Methane	wwt/a/bf	0.43	0.70	1.55	0.48	14.00
157	Oil content	wwt/a/bf	0.41	0.67	0.00	0.00	7.37
158	Wastewater, Municipal	wwt/a/bf	0.41	0.66	0.86	0.61	9.03
159	BOD	wwt/a/bf	0.41	0.66	4.87	5.28	8.85
160	Fermentation	wwt/a/bf	0.40	0.65	0.00	0.00	16.80
161	Ecology	wwt/a/bf	0.40	0.65	0.09	2.62	7.79
162	*Scenedesmus*	wwt/a/bf	0.36	0.58	0.00	1.88	6.53
163	Greenhouse gases	wwt/a/bf	0.36	0.58	0.00	0.00	13.50
164	Nitrogen removal	wwt/a/bf	0.33	0.53	3.13	2.75	6.18
165	Agriculture	wwt/a/bf	0.32	0.52	2.14	2.32	8.74
166	Water recycling	wwt/a/bf	0.30	0.49	2.46	1.57	3.20
167	Carbon	wwt/a/bf	0.28	0.46	4.16	3.78	6.75

	Keyword (2000 to 2015)	Dataset where keyword is dominant	Dissimilarity		Mean abundance (%)		
			Average	Contribution (%)	wwt (2000-2015)	wwt/a (2000-2015)	wwt/a/bf (2006-2015)
168	Anaerobiosis	wwt/a/bf	0.28	0.45	1.42	0.00	7.92
169	Phytoplankton	wwt/a/bf	0.27	0.44	0.00	2.36	4.23
170	Bioprocess	wwt/a/bf	0.27	0.43	1.35	2.67	2.68
171	Electron transport	wwt/a/bf	0.25	0.41	0.00	0.00	11.00
172	Lake	wwt/a/bf	0.25	0.41	0.00	2.58	3.64
173	Growth	wwt/a/bf	0.25	0.41	0.11	1.25	4.59
174	Carbohydrate	wwt/a/bf	0.24	0.39	0.00	0.00	8.18
175	Light	wwt/a/bf	0.23	0.37	0.00	0.15	5.43
176	Hydraulic retention time	wwt/a/bf	0.22	0.36	0.54	1.36	5.39
177	Nitrates	wwt/a/bf	0.22	0.35	2.75	1.75	2.87
178	Electrochemistry	wwt/a/bf	0.21	0.33	0.50	0.24	4.70
179	Organic Carbon	wwt/a/bf	0.20	0.33	1.03	0.34	5.74
180	Calorimetry	wwt/a/bf	0.19	0.31	0.00	0.00	9.30
181	Sugars	wwt/a/bf	0.19	0.31	0.00	0.16	9.09
182	Cell Cultivation	wwt/a/bf	0.19	0.30	0.00	0.84	3.90
183	Bioelectric	wwt/a/bf	0.19	0.30	0.00	0.00	5.17
184	Flocculation	wwt/a/bf	0.18	0.30	2.08	1.90	3.49
185	Wastewaters, dairy	wwt/a/bf	0.18	0.29	0.00	0.00	4.98
186	Life Cycle Assessment (LCA)	wwt/a/bf	0.15	0.25	0.00	0.00	3.75
187	Extraction	wwt/a/bf	0.15	0.25	0.86	0.00	4.76
188	Nutrition	wwt/a/bf	0.13	0.21	0.00	0.47	4.85
189	Lipid production	wwt/a/bf	0.13	0.21	0.00	0.00	2.88
190	Microalgae cultivation	wwt/a/bf	0.12	0.20	0.00	0.11	2.68
191	Water resources	wwt/a/bf	0.12	0.20	0.97	0.21	1.63
192	Anaerobic growth	wwt/a/bf	0.12	0.19	0.00	0.00	5.20
193	Energy crops	wwt/a/bf	0.12	0.19	0.00	0.00	5.24
194	Lipid content	wwt/a/bf	0.12	0.19	0.00	0.00	2.97
195	Batch reactors	wwt/a/bf	0.11	0.18	0.63	0.37	1.70
196	Fungi	wwt/a/bf	0.11	0.18	0.00	1.00	1.65
197	Seawater	wwt/a/bf	0.10	0.16	0.00	0.78	1.55
198	Costs	wwt/a/bf	0.09	0.15	0.85	0.17	1.14
199	Biochemistry	wwt/a/bf	0.09	0.14	0.20	0.80	0.93
200	High Rate Pond	wwt/a/bf	0.09	0.14	0.00	0.22	1.81
201	Dry weight	wwt/a/bf	0.09	0.14	0.00	0.00	2.37
202	Glucose	wwt/a/bf	0.08	0.14	0.00	0.00	2.05
203	Manure	wwt/a/bf	0.08	0.13	0.00	0.00	1.95
204	Mixotrophy	wwt/a/bf	0.08	0.13	0.00	0.00	1.89
205	Eukaryota	wwt/a/bf	0.08	0.12	0.00	0.42	1.53
206	Lipid metabolism	wwt/a/bf	0.08	0.12	0.00	0.00	1.79
207	Growth medium	wwt/a/bf	0.07	0.11	0.00	0.00	1.90
208	Wastewater Swine	wwt/a/bf	0.07	0.11	0.00	0.00	1.49
209	Bioconversion	wwt/a/bf	0.06	0.10	0.11	0.00	1.53
210	Flue gases	wwt/a/bf	0.06	0.10	0.00	0.00	1.67
211	Proteins	wwt/a/bf	0.06	0.10	0.00	0.00	1.42
212	Microbial Biomass	wwt/a/bf	0.05	0.09	0.00	0.22	0.96
213	Sodium	wwt/a/bf	0.05	0.09	0.26	0.22	0.70
214	Physiology	wwt/a/bf	0.05	0.08	0.16	0.14	0.82
215	Lipid composition	wwt/a/bf	0.05	0.08	0.00	0.00	1.24
216	Nutrient availability	wwt/a/bf	0.04	0.07	0.00	0.00	0.97
217	*Acutodesmus obliquus*	wwt/a/bf	0.04	0.07	0.00	0.00	1.02
218	Lipid storage	wwt/a/bf	0.04	0.07	0.00	0.00	0.95
219	Spirulina	wwt/a/bf	0.04	0.07	0.00	0.00	1.01
220	Animal feed	wwt/a/bf	0.04	0.06	0.00	0.00	1.00
221	*Chlorella pyrenoidosa*	wwt/a/bf	0.04	0.06	0.00	0.00	0.85
222	Environment	wwt/a/bf	0.04	0.06	0.00	0.18	0.70
223	Biodiversity	wwt/a/bf	0.04	0.06	0.00	0.16	0.70
224	Sludge digestion	wwt/a/bf	0.04	0.06	0.14	0.00	0.70
225	Nutrient uptake	wwt/a/bf	0.03	0.05	0.00	0.00	0.78
226	Bioethanol	wwt/a/bf	0.03	0.05	0.00	0.00	0.77
227	Phycoremediation	wwt/a/bf	0.03	0.04	0.00	0.00	0.54
228	Bioactivity	wwt/a/bf	0.02	0.04	0.20	0.00	0.35
229	Genetics	wwt/a/bf	0.02	0.04	0.13	0.00	0.37
230	Acetic acid	wwt/a/bf	0.02	0.04	0.09	0.00	0.38

Supplementary Table 2: Keywords inducing dissimilarities between publication datasets for years 1970 to 2015 (SIMPER analysis, Hammer et al., 2001); SIMPER analysis was carried out on keyword intensity datasets.

	Keyword (1970 to 2015)	Dataset where keyword is dominant	Dissimilarity		Mean abundance (%)		
			Average	Contribution (%)	wwt (2000-2015)	wwt/a (2000-2015)	wwt/a/bf (2006-2015)
1	Environmental impact	wwt	0.89	1.25	9.32	7.40	0.35
2	Industrial waste	wwt	0.77	1.09	9.37	7.33	7.28
3	Activated sludge	wwt	0.66	0.92	9.11	4.65	4.79
4	Filtration	wwt	0.53	0.75	5.15	4.95	0.83
5	Oxidation	wwt	0.42	0.59	3.52	2.69	2.27
6	Wastewater, paper mill	wwt	0.40	0.57	2.74	2.35	0.00
7	Sludge	wwt	0.34	0.48	3.83	2.11	0.42
8	Water supply	wwt	0.33	0.46	3.63	1.87	1.94
9	Nitrification	wwt	0.29	0.41	3.13	1.96	0.29
10	Denitrification	wwt	0.28	0.40	2.89	1.78	0.00
11	Membrane bioreactor	wwt	0.26	0.37	2.63	0.05	1.75
12	Water management	wwt	0.25	0.35	1.91	1.77	1.90
13	Reaction kinetics	wwt	0.24	0.33	2.49	1.78	0.00
14	Phenols	wwt	0.23	0.32	2.50	0.54	0.00
15	Irrigation	wwt	0.22	0.31	1.78	1.33	0.00
16	Aeration	wwt	0.22	0.31	1.62	1.23	0.38
17	Costs	wwt	0.21	0.30	1.80	1.03	1.14
18	Activated carbon	wwt	0.20	0.28	2.13	1.17	0.00
19	Sanitation	wwt	0.19	0.27	1.23	0.94	0.00
20	Waste disposal	wwt	0.18	0.25	1.70	0.37	0.00
21	Groundwater	wwt	0.17	0.23	1.48	0.81	0.00
22	Ozonation	wwt	0.16	0.22	1.07	0.67	0.00
23	Soil	wwt	0.14	0.20	1.22	0.55	0.00
24	Sludge disposal	wwt	0.14	0.19	0.93	0.70	0.00
25	Iron	wwt	0.12	0.16	0.98	0.88	0.00
26	Law and regulations	wwt	0.12	0.16	0.73	0.62	0.00
27	Oxidation-reduction	wwt	0.11	0.15	1.15	0.21	0.00
28	Wastewater disposal	wwt	0.09	0.13	0.92	0.29	0.00
29	Contamination	wwt	0.07	0.10	0.57	0.39	0.00
30	Hydrogen peroxide	wwt	0.07	0.10	0.64	0.17	0.00
31	*Gadus morhua*	wwt	0.07	0.09	0.66	0.17	0.00
32	Ultraviolet radiation	wwt	0.06	0.09	0.49	0.27	0.00
33	Reactors	wwt	0.06	0.08	0.64	0.00	0.00
34	Ultrafiltration	wwt	0.06	0.08	0.67	0.00	0.00
35	Mass spectrometry	wwt	0.06	0.08	0.58	0.14	0.00
36	Reverse osmosis	wwt	0.06	0.08	0.54	0.00	0.00
37	Diseases	wwt	0.04	0.06	0.25	0.13	0.00
38	Photocatalysis	wwt	0.03	0.04	0.33	0.00	0.00
39	Acids	wwt	0.02	0.03	0.19	0.12	0.00
40	X ray diffraction	wwt	0.02	0.03	0.26	0.00	0.00
41	Titanium dioxide	wwt	0.02	0.03	0.26	0.00	0.00
42	Methanogenesis	wwt	0.02	0.03	0.13	0.08	0.00
43	Volatile Pollutants/pollution	wwt	0.02	0.02	0.20	0.00	0.00
44	Sequencing batch reactors	wwt	0.02	0.02	0.11	0.07	0.00
45	Desalination	wwt	0.02	0.02	0.14	0.00	0.00
46	Water reclamation	wwt	0.01	0.02	0.15	0.00	0.00

	Keyword (1970 to 2015)	Dataset where keyword is dominant	Dissimilarity		Mean abundance (%)		
			Average	Contribution (%)	wwt (2000-2015)	wwt/a (2000-2015)	wwt/a/bf (2006-2015)
47	Fouling	wwt	0.01	0.02	0.11	0.07	0.00
48	Detergents	wwt	0.01	0.02	0.08	0.07	0.00
49	Sludge dewatering	wwt	0.01	0.02	0.13	0.00	0.00
50	Drainage	wwt	0.01	0.01	0.10	0.00	0.00
51	Liquid chromatography	wwt	0.01	0.01	0.08	0.00	0.00
52	Photodegradation	wwt	0.01	0.01	0.08	0.00	0.00
53	Aromatic compounds	wwt	0.01	0.01	0.07	0.00	0.00
54	Transmission electron microscopy	wwt	0.01	0.01	0.07	0.00	0.00
55	Water reuse	wwt	0.01	0.01	0.06	0.00	0.00
56	Sulfur	wwt	0.00	0.01	0.05	0.00	0.00
57	Polymers	wwt	0.00	0.01	0.05	0.00	0.00
58	Biological filtration beds	wwt	0.00	0.01	0.04	0.00	0.00
59	Aerobic treatment	wwt	0.00	0.01	0.04	0.00	0.00
60	Nutrient removal	wwt/a	1.64	2.30	7.57	19.90	16.70
61	Management	wwt/a	1.59	2.23	18.80	26.90	20.70
62	Water Pollutants/pollution	wwt/a	1.28	1.80	16.40	20.40	5.89
63	Sorption	wwt/a	1.08	1.52	0.50	13.50	0.00
64	Modeling	wwt/a	1.06	1.49	11.90	14.20	0.42
65	pH	wwt/a	1.04	1.46	5.76	12.90	5.36
66	Adsorption	wwt/a	1.02	1.43	5.07	12.40	0.00
67	Heavy metals	wwt/a	0.74	1.04	3.70	9.83	0.21
68	Pond	wwt/a	0.70	0.99	0.17	8.01	3.60
69	Water quality	wwt/a	0.68	0.96	5.50	10.50	3.44
70	Eutrophication	wwt/a	0.63	0.88	0.12	6.96	1.66
71	Biodegradation	wwt/a	0.62	0.87	5.65	7.23	6.90
72	Toxicity	wwt/a	0.57	0.81	2.03	7.26	0.98
73	Pollutants/pollution	wwt/a	0.53	0.75	4.53	6.60	5.41
74	Chemical Oxygen Demand	wwt/a	0.53	0.75	6.17	6.57	6.39
75	Ammonia(um)	wwt/a	0.51	0.72	3.27	7.00	4.75
76	Lake	wwt/a	0.48	0.67	0.09	4.30	3.64
77	Microbiology	wwt/a	0.46	0.65	4.03	4.06	3.14
78	Stabilization pond	wwt/a	0.44	0.62	0.18	5.45	0.00
79	Rivers	wwt/a	0.42	0.60	1.28	4.77	0.70
80	Copper	wwt/a	0.40	0.56	1.53	5.16	0.00
81	Bioprocess	wwt/a	0.39	0.54	1.53	3.55	2.68
82	Cadmium	wwt/a	0.38	0.54	0.86	4.78	0.00
83	Kinetics	wwt/a	0.37	0.52	2.29	4.11	0.78
84	Temperature	wwt/a	0.35	0.49	2.04	4.05	3.10
85	Fisheries	wwt/a	0.33	0.47	0.28	3.59	0.00
86	Chromium	wwt/a	0.31	0.43	1.09	3.60	0.00
87	Lagoons	wwt/a	0.30	0.43	0.08	3.10	0.00
88	Isotherms	wwt/a	0.30	0.42	0.09	3.65	0.00
89	Wastewater, industrial	wwt/a	0.29	0.40	2.58	2.74	0.00
90	Chlorine/chloride	wwt/a	0.29	0.40	0.70	2.53	0.00
91	Dyes	wwt/a	0.28	0.40	1.84	2.24	0.83
92	Ecosystems	wwt/a	0.28	0.40	0.25	3.42	0.00
93	Drug	wwt/a	0.25	0.36	1.40	2.11	0.96
94	Organic matter	wwt/a	0.25	0.35	1.29	2.78	0.00
95	Surface waters	wwt/a	0.25	0.35	0.60	2.44	0.00
96	Coliforms	wwt/a	0.24	0.34	0.39	2.53	0.00
97	Zinc	wwt/a	0.23	0.33	1.17	2.65	0.00
98	Food industry	wwt/a	0.23	0.32	0.52	1.79	0.83
99	Aquaculture	wwt/a	0.22	0.31	0.06	2.41	0.00
100	*Daphnia*	wwt/a	0.20	0.29	0.00	2.38	0.00
101	Disinfection	wwt/a	0.19	0.27	0.92	1.32	0.83
102	Toxicity testing	wwt/a	0.19	0.26	0.02	2.32	0.00
103	Metals	wwt/a	0.18	0.26	0.38	2.18	0.00
104	Dissolved Oxygen demand	wwt/a	0.18	0.25	0.43	1.82	0.29
105	Oxidation pond	wwt/a	0.17	0.24	0.00	1.84	0.00
106	Bioaccumulation	wwt/a	0.17	0.24	0.00	1.99	0.38
107	Bioassay	wwt/a	0.17	0.24	0.02	2.00	0.00
108	Wetland	wwt/a	0.16	0.22	0.47	0.70	0.00

	Keyword (1970 to 2015)	Dataset where keyword is dominant	Dissimilarity		Mean abundance (%)		
			Average	Contribution (%)	wwt (2000-2015)	wwt/a (2000-2015)	wwt/a/bf (2006-2015)
109	Viruses	wwt/a	0.15	0.21	0.17	1.36	0.00
110	Nickel	wwt/a	0.15	0.20	0.21	1.74	0.00
111	Thermodynamics	wwt/a	0.14	0.20	0.18	1.64	0.00
112	Drinking water	wwt/a	0.14	0.19	0.60	1.12	0.00
113	Metals ion	wwt/a	0.13	0.19	0.31	1.41	0.00
114	*Lemna*	wwt/a	0.13	0.18	0.00	1.53	0.00
115	Engineering	wwt/a	0.13	0.18	0.74	0.81	0.00
116	Arthropod	wwt/a	0.12	0.17	0.02	1.28	0.00
117	Water contamination	wwt/a	0.12	0.17	0.74	1.09	0.00
118	Land application	wwt/a	0.11	0.16	0.54	0.64	0.00
119	Marine biology	wwt/a	0.11	0.15	0.01	1.11	0.00
120	Fertilizers	wwt/a	0.11	0.15	0.18	0.93	0.00
121	Scanning electron microscopy	wwt/a	0.11	0.15	0.55	0.84	0.00
122	Performance assessment	wwt/a	0.10	0.15	0.65	0.85	0.00
123	Invertebrate	wwt/a	0.10	0.14	0.04	0.97	0.00
124	Risk assessment	wwt/a	0.10	0.13	0.21	1.03	0.00
125	Sludge stabilization	wwt/a	0.09	0.13	0.03	0.98	0.00
126	Wastewater, textile mills	wwt/a	0.09	0.12	0.42	0.53	0.00
127	*Escherichia coli*	wwt/a	0.08	0.11	0.35	0.58	0.00
128	Ecotoxicology	wwt/a	0.08	0.11	0.00	0.91	0.00
129	Chemical industry	wwt/a	0.07	0.11	0.22	0.64	0.00
130	Coastal	wwt/a	0.07	0.10	0.05	0.87	0.00
131	Water sampling	wwt/a	0.07	0.10	0.43	0.58	0.00
132	Calcium	wwt/a	0.07	0.10	0.05	0.77	0.00
133	Immobilization	wwt/a	0.07	0.10	0.00	0.84	0.00
134	Precipitation	wwt/a	0.07	0.09	0.38	0.48	0.00
135	Zooplankton	wwt/a	0.06	0.09	0.00	0.81	0.00
136	Enzyme	wwt/a	0.06	0.09	0.05	0.61	0.00
137	Seawater weed	wwt/a	0.06	0.09	0.00	0.74	0.00
138	Odor	wwt/a	0.06	0.08	0.14	0.55	0.00
139	Animal	wwt/a	0.06	0.08	0.18	0.39	0.35
140	Infrared spectroscopy	wwt/a	0.06	0.08	0.04	0.65	0.00
141	Food	wwt/a	0.06	0.08	0.00	0.59	0.00
142	Macrophyte	wwt/a	0.06	0.08	0.00	0.68	0.00
143	Wastewater reuse	wwt/a	0.05	0.07	0.18	0.40	0.00
144	Septic tank	wwt/a	0.05	0.07	0.10	0.44	0.00
145	*Selenastrum*	wwt/a	0.05	0.07	0.00	0.51	0.00
146	*Chlamydomonas*	wwt/a	0.05	0.07	0.00	0.44	0.38
147	Wastewater, poultry	wwt/a	0.05	0.07	0.03	0.45	0.00
148	Farm waste treatment	wwt/a	0.04	0.06	0.01	0.45	0.00
149	Nitrite	wwt/a	0.04	0.06	0.07	0.46	0.00
150	Wastewater standard	wwt/a	0.04	0.06	0.13	0.42	0.00
151	Chromatography	wwt/a	0.04	0.06	0.18	0.31	0.00
152	Operational regime	wwt/a	0.04	0.06	0.00	0.50	0.00
153	Wastewater, mine	wwt/a	0.04	0.06	0.05	0.35	0.00
154	Hazardous materials	wwt/a	0.04	0.06	0.24	0.29	0.00
155	Mercury	wwt/a	0.04	0.06	0.04	0.35	0.00
156	Absorption	wwt/a	0.04	0.05	0.01	0.50	0.00
157	Phosphoric acid	wwt/a	0.04	0.05	0.04	0.30	0.00
158	*Ceriodaphnia*	wwt/a	0.04	0.05	0.00	0.38	0
159	Isotopes	wwt/a	0.04	0.05	0.05	0.34	0.00
160	Alkalinity	wwt/a	0.03	0.05	0.04	0.37	0.00
161	Crustacea	wwt/a	0.03	0.05	0.01	0.34	0.00
162	Radioactive	wwt/a	0.03	0.05	0.05	0.29	0.00
163	Periphyton	wwt/a	0.03	0.05	0.01	0.37	0.00
164	Turbidity	wwt/a	0.03	0.05	0.00	0.42	0.00
165	Polychlorinated bisphenols	wwt/a	0.03	0.05	0.03	0.29	0.00
166	Diatom	wwt/a	0.03	0.04	0.00	0.33	0.00
167	Carageenan	wwt/a	0.03	0.04	0.00	0.32	0.00
168	Toxic materials	wwt/a	0.03	0.04	0.00	0.39	0.00
169	Sargassum	wwt/a	0.03	0.04	0.00	0.32	0.00
170	Fourier transform infrared spectroscopy	wwt/a	0.03	0.04	0.09	0.25	0.00

	Keyword (1970 to 2015)	Dataset where keyword is dominant	Dissimilarity		Mean abundance (%)		
			Average	Contribution (%)	wwt (2000-2015)	wwt/a (2000-2015)	wwt/a/bf (2006-2015)
171	Mollusks	wwt/a	0.03	0.04	0.00	0.30	0.00
172	15N tracer	wwt/a	0.03	0.04	0.00	0.30	0.00
173	Organization and management	wwt/a	0.03	0.04	0.12	0.13	0.00
174	Nitrogen fixation	wwt/a	0.03	0.04	0.00	0.31	0.00
175	Slurry	wwt/a	0.03	0.04	0.00	0.29	0.00
176	Trace element	wwt/a	0.03	0.04	0.00	0.29	0.00
177	Magnesium	wwt/a	0.03	0.04	0.00	0.28	0.00
178	Sludge settling tanks	wwt/a	0.02	0.04	0.08	0.18	0
179	Sea	wwt/a	0.02	0.03	0.04	0.21	0.00
180	*Eichhornia crassipes*	wwt/a	0.02	0.03	0.00	0.24	0.00
181	*Bacillariophyta*	wwt/a	0.02	0.03	0.00	0.26	0.00
182	Calcium (bi)Carbonate	wwt/a	0.02	0.03	0.00	0.23	0.00
183	Alginate	wwt/a	0.02	0.03	0.00	0.29	0.00
184	Clarifiers	wwt/a	0.02	0.03	0.02	0.20	0.00
185	Slaughterhouse	wwt/a	0.02	0.03	0.00	0.21	0.00
186	Microcystis	wwt/a	0.02	0.03	0.00	0.21	0.00
187	Protozoa	wwt/a	0.02	0.03	0.00	0.21	0.00
188	Mining	wwt/a	0.02	0.03	0.03	0.20	0.00
189	Gas chromatography	wwt/a	0.02	0.03	0.05	0.17	0.00
190	Biomonitoring	wwt/a	0.02	0.03	0.00	0.21	0.00
191	Anaerobic metabolism	wwt/a	0.02	0.03	0.09	0.16	0.00
192	Wastewater, canning	wwt/a	0.02	0.03	0.00	0.19	0.00
193	Spectroscopy	wwt/a	0.02	0.03	0.02	0.18	0.00
194	Bloom	wwt/a	0.02	0.03	0.00	0.18	0.00
195	Limnology	wwt/a	0.02	0.03	0.01	0.17	0.00
196	Fixed-bed Reactors	wwt/a	0.02	0.03	0.02	0.16	0.00
197	*Giardia*	wwt/a	0.02	0.02	0.00	0.18	0.00
198	Marine environment	wwt/a	0.02	0.02	0.00	0.23	0.00
199	Fly ash	wwt/a	0.02	0.02	0.02	0.13	0.00
200	Poultry	wwt/a	0.02	0.02	0.00	0.16	0.00
201	Marine Pollutants/pollution	wwt/a	0.02	0.02	0.00	0.21	0.00
202	*Tracheophyta*	wwt/a	0.02	0.02	0.00	0.15	0.00
203	Potassium	wwt/a	0.02	0.02	0.00	0.18	0.00
204	*Ulva*	wwt/a	0.01	0.02	0.00	0.16	0.00
205	Liquid-solid separation	wwt/a	0.01	0.02	0.04	0.15	0.00
206	*Cladocera*	wwt/a	0.01	0.02	0.00	0.16	0.00
207	Enzyme kinetics	wwt/a	0.01	0.02	0.00	0.13	0.00
208	Acidity	wwt/a	0.01	0.02	0.00	0.18	0.00
209	Wastewaters, cyanide	wwt/a	0.01	0.02	0.04	0.09	0.00
210	Pesticide	wwt/a	0.01	0.02	0.03	0.10	0.00
211	Cation	wwt/a	0.01	0.02	0.00	0.16	0.00
212	Sulfide	wwt/a	0.01	0.02	0.02	0.13	0.00
213	Antibiotics	wwt/a	0.01	0.02	0.05	0.07	0.00
214	Wastewater, process	wwt/a	0.01	0.02	0.03	0.09	0.00
215	Cattle	wwt/a	0.01	0.02	0.00	0.13	0.00
216	Hazardous waste	wwt/a	0.01	0.02	0.04	0.09	0.00
217	Arsenic	wwt/a	0.01	0.01	0.00	0.12	0.00
218	Sludge bulking	wwt/a	0.01	0.01	0.02	0.09	0.00
219	Calcium oxide	wwt/a	0.01	0.01	0.01	0.09	0.00
220	Surfactant	wwt/a	0.01	0.01	0.02	0.08	0.00
221	Aerobic metabolism	wwt/a	0.01	0.01	0.04	0.05	0.00
222	Biomass	wwt/a/bf	2.84	4.00	3.39	17.80	72.80
223	Bacteria	wwt/a/bf	1.63	2.30	8.72	20.40	30.40
224	Phosphorus	wwt/a/bf	1.13	1.59	4.31	14.30	17.00
225	Nutrient	wwt/a/bf	1.04	1.46	1.15	8.59	18.30
226	Nitrogen	wwt/a/bf	1.02	1.44	4.81	12.70	16.50
227	Microorganisms	wwt/a/bf	0.93	1.31	2.77	5.63	23.80
228	*Chlorella*	wwt/a/bf	0.91	1.28	0.00	4.70	23.20
229	Bioreactor	wwt/a/bf	0.87	1.22	7.94	6.68	16.80
230	CO2/carbon	wwt/a/bf	0.87	1.22	0.12	1.59	34.90
231	Anaerobic digester	wwt/a/bf	0.70	0.98	3.60	1.84	25.50
232	Cultivation	wwt/a/bf	0.68	0.95	0.06	2.58	17.10

	Keyword (1970 to 2015)	Dataset where keyword is dominant	Dissimilarity		Mean abundance (%)		
			Average	Contribution (%)	wwt (2000-2015)	wwt/a (2000-2015)	wwt/a/bf (2006-2015)
233	Chlorophyll	wwt/a/bf	0.61	0.86	0.00	6.02	7.28
234	Cyanobacteria/ bluegreen algae	wwt/a/bf	0.60	0.85	0.00	5.78	0.0682
235	Water purification	wwt/a/bf	0.59	0.83	2.90	4.96	7.02
236	Ecology	wwt/a/bf	0.57	0.80	0.84	4.73	7.79
237	Photosynthesis	wwt/a/bf	0.55	0.77	0.01	3.95	12.70
238	Lipid	wwt/a/bf	0.54	0.76	0.00	1.12	16.60
239	Energy	wwt/a/bf	0.54	0.76	0.22	0.55	18.30
240	Wastewater reclamation	wwt/a/bf	0.54	0.75	3.36	2.40	9.56
241	Bod	wwt/a/bf	0.53	0.75	4.09	7.04	8.85
242	Fatty acid	wwt/a/bf	0.50	0.70	0.00	0.56	23.80
243	Oxygen demand	wwt/a/bf	0.44	0.62	3.07	3.49	4.82
244	Electricity	wwt/a/bf	0.44	0.61	0.07	0.28	15.20
245	Growth rate	wwt/a/bf	0.43	0.61	0.00	2.47	9.57
246	Biotechnology	wwt/a/bf	0.43	0.61	0.58	2.57	10.20
247	Metabolism	wwt/a/bf	0.43	0.61	1.16	2.13	12.30
248	Renewable resources	wwt/a/bf	0.41	0.58	0.05	0.28	19.20
249	Bioremediation	wwt/a/bf	0.40	0.56	0.96	3.42	6.23
250	Photobioreactor	wwt/a/bf	0.38	0.54	0.00	0.66	11.90
251	Wastewater, municipal	wwt/a/bf	0.37	0.52	0.56	1.43	9.03
252	Nitrogen removal	wwt/a/bf	0.36	0.50	1.56	2.36	6.18
253	Carbon	wwt/a/bf	0.34	0.48	2.17	2.41	6.75
254	Energy production	wwt/a/bf	0.34	0.48	0.00	0.07	18.90
255	*Scenedesmus*	wwt/a/bf	0.34	0.47	0.00	2.03	6.53
256	Methane	wwt/a/bf	0.32	0.46	1.16	0.36	14.00
257	Agriculture	wwt/a/bf	0.32	0.45	1.21	2.27	8.74
258	Phytoplankton	wwt/a/bf	0.31	0.44	0.03	2.82	4.23
259	Ethanol	wwt/a/bf	0.31	0.43	0.00	0.00	15.30
260	Oil content	wwt/a/bf	0.30	0.42	0.12	0.07	7.37
261	Fermentation	wwt/a/bf	0.28	0.40	0.18	0.35	16.80
262	Flocculation	wwt/a/bf	0.28	0.40	1.31	2.69	3.49
263	Growth	wwt/a/bf	0.28	0.40	0.09	1.92	4.59
264	Nitrates	wwt/a/bf	0.28	0.39	1.80	2.18	2.87
265	Biofilm	wwt/a/bf	0.28	0.39	2.57	1.15	2.72
266	Cell cultivation	wwt/a/bf	0.25	0.35	0.00	2.02	3.90
267	Economics	wwt/a/bf	0.24	0.34	1.26	1.16	1.65
268	Agricultural wastes	wwt/a/bf	0.23	0.32	0.17	1.13	9.09
269	Water recycling	wwt/a/bf	0.22	0.31	1.33	0.87	3.20
270	Greenhouse gases	wwt/a/bf	0.22	0.31	0.00	0.00	13.50
271	Water resources	wwt/a/bf	0.21	0.30	1.49	0.71	1.63
272	Light	wwt/a/bf	0.19	0.27	0.00	0.69	5.43
273	Anaerobiosis	wwt/a/bf	0.17	0.24	0.54	0.00	7.92
274	Carbohydrate	wwt/a/bf	0.17	0.24	0.00	0.20	8.18
275	Coagulation	wwt/a/bf	0.16	0.22	0.90	1.05	1.11
276	Electron transport	wwt/a/bf	0.15	0.22	0.00	0.00	11.00
277	Optimization	wwt/a/bf	0.15	0.22	1.22	0.51	1.93
278	Hydraulic retention time	wwt/a/bf	0.15	0.22	0.20	0.75	5.39
279	Proteins	wwt/a/bf	0.15	0.22	0.00	1.23	1.42
280	High rate pond	wwt/a/bf	0.14	0.20	0.02	1.08	1.81
281	Fungi	wwt/a/bf	0.14	0.19	0.09	1.16	1.65
282	Organic carbon	wwt/a/bf	0.13	0.18	0.39	0.15	5.74
283	Wastewaters, dairy	wwt/a/bf	0.13	0.18	0.00	0.20	4.98
284	Seawater	wwt/a/bf	0.13	0.18	0.09	1.08	1.55
285	Electrochemistry	wwt/a/bf	0.13	0.18	0.22	0.10	4.70
286	Manure	wwt/a/bf	0.12	0.17	0.03	0.88	1.95
287	Sugars	wwt/a/bf	0.12	0.17	0.01	0.14	9.09
288	Calorimetry	wwt/a/bf	0.12	0.16	0.00	0.00	9.30
289	Biochemistry	wwt/a/bf	0.12	0.16	0.30	0.82	0.93
290	Bioelectric	wwt/a/bf	0.11	0.16	0.00	0.00	5.17
291	Life cycle assessment (lca)	wwt/a/bf	0.10	0.14	0.00	0.00	3.75
292	Solar radiation	wwt/a/bf	0.10	0.14	0.00	0.80	1.65
293	Swine	wwt/a/bf	0.10	0.13	0.00	0.62	1.49
294	Extraction	wwt/a/bf	0.10	0.13	0.36	0.07	4.76
295	Petrochemical industry	wwt/a/bf	0.09	0.13	0.35	0.46	0.56

	Keyword (1970 to 2015)	Dataset where keyword is dominant	Dissimilarity		Mean abundance (%)		
			Average	Contribution (%)	wwt (2000-2015)	wwt/a (2000-2015)	wwt/a/bf (2006-2015)
296	Isolation and purification	wwt/a/bf	0.09	0.12	0.44	0.39	1.01
297	Lipid production	wwt/a/bf	0.08	0.12	0.00	0.00	2.88
298	Nutrition	wwt/a/bf	0.08	0.12	0.00	0.26	4.85
299	Fresh water	wwt/a/bf	0.08	0.12	0.00	0.73	0.93
300	Coal gasification	wwt/a/bf	0.08	0.11	0.18	0.50	0.70
301	Animal feed	wwt/a/bf	0.08	0.11	0.00	0.56	1.00
302	Carbonate	wwt/a/bf	0.08	0.11	0.00	0.11	3.31
303	Lipid content	wwt/a/bf	0.08	0.11	0.00	0.00	2.97
304	Anaerobic growth	wwt/a/bf	0.07	0.10	0.02	0.00	5.20
305	Batch reactors	wwt/a/bf	0.07	0.10	0.23	0.16	1.70
306	Glucose	wwt/a/bf	0.07	0.10	0.03	0.20	2.05
307	Energy crops	wwt/a/bf	0.07	0.10	0.00	0.00	5.24
308	Catalysis	wwt/a/bf	0.07	0.10	0.67	0.00	0.83
309	Microbial activity	wwt/a/bf	0.07	0.10	0.39	0.39	0.47
310	Dry weight	wwt/a/bf	0.07	0.10	0.00	0.19	2.37
311	Sludge digestion	wwt/a/bf	0.06	0.09	0.55	0.00	0.70
312	Microbial community	wwt/a/bf	0.06	0.09	0.38	0.20	0.64
313	Sodium	wwt/a/bf	0.06	0.09	0.09	0.41	0.70
314	Acetic acid	wwt/a/bf	0.06	0.08	0.34	0.28	0.38
315	Eukaryota	wwt/a/bf	0.05	0.07	0.00	0.25	1.53
316	Mixotrophy	wwt/a/bf	0.05	0.07	0.00	0.00	1.89
317	Lipid metabolism	wwt/a/bf	0.05	0.07	0.00	0.00	1.79
318	Environment	wwt/a/bf	0.05	0.07	0.02	0.37	0.70
319	Bioconversion	wwt/a/bf	0.05	0.07	0.04	0.10	1.53
320	Waste Nutrient removal	wwt/a/bf	0.05	0.07	0.34	0.00	0.83
321	Fluidized bed Reactors	wwt/a/bf	0.05	0.07	0.24	0.12	0.83
322	Wastewater, distillery	wwt/a/bf	0.05	0.06	0.00	0.29	0.83
323	*Chlorella pyrenoidosa*	wwt/a/bf	0.05	0.06	0.00	0.26	0.85
324	Air Pollutants/pollution	wwt/a/bf	0.04	0.06	0.26	0.09	0.47
325	Growth medium	wwt/a/bf	0.04	0.06	0.00	0.00	1.90
326	Physiology	wwt/a/bf	0.04	0.06	0.06	0.17	0.82
327	Flue gases	wwt/a/bf	0.04	0.05	0.00	0.00	1.67
328	Lipid composition	wwt/a/bf	0.04	0.05	0.00	0.05	1.24
329	Microbial biomass	wwt/a/bf	0.04	0.05	0.00	0.09	0.96
330	Aerobiosis	wwt/a/bf	0.04	0.05	0.02	0.00	1.65
331	Dewatering	wwt/a/bf	0.03	0.05	0.18	0.17	0.29
332	Nutrient availability	wwt/a/bf	0.03	0.04	0.00	0.00	0.97
333	Genetics	wwt/a/bf	0.03	0.04	0.05	0.17	0.37
334	*Acutodesmus obliquus*	wwt/a/bf	0.03	0.04	0.00	0.00	1.02
335	Nutrient uptake	wwt/a/bf	0.03	0.04	0.00	0.08	0.78
336	Pilot scale/plant	wwt/a/bf	0.03	0.04	0.04	0.13	0.37
337	Lipid storage	wwt/a/bf	0.03	0.04	0.00	0.00	0.95
338	Carotenoid	wwt/a/bf	0.03	0.04	0.00	0.11	0.70
339	*Spirulina*	wwt/a/bf	0.03	0.04	0.00	0.00	1.01
340	Biosynthesis	wwt/a/bf	0.02	0.03	0.00	0.07	0.64
341	Hydrolysis	wwt/a/bf	0.02	0.03	0.05	0.11	0.35
342	Brewery wastewater	wwt/a/bf	0.02	0.03	0.00	0.15	0.21
343	Nanoparticles	wwt/a/bf	0.02	0.03	0.11	0.07	0.21
344	Biodiversity	wwt/a/bf	0.02	0.03	0.00	0.07	0.70
345	Brackish water	wwt/a/bf	0.02	0.03	0.00	0.06	0.70
346	Heterotrophy	wwt/a/bf	0.02	0.03	0.00	0.09	0.46
347	Bioethanol	wwt/a/bf	0.02	0.03	0.00	0.00	0.77
348	Land use	wwt/a/bf	0.02	0.03	0.00	0.09	0.47
349	Design	wwt/a/bf	0.02	0.03	0.01	0.00	0.83
350	Bicarbonate	wwt/a/bf	0.02	0.02	0.00	0.09	0.35
351	Phycoremediation	wwt/a/bf	0.02	0.02	0.00	0.00	0.54
352	Glycerol	wwt/a/bf	0.02	0.02	0.00	0.07	0.28
353	Forestry	wwt/a/bf	0.01	0.02	0.03	0.00	0.47
354	Bioactivity	wwt/a/bf	0.01	0.02	0.07	0.00	0.35