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Bibliometrics of a controversial scientific literature: Polywater research, 1962–1974

ERIC ACKERMANN

McConnell Library, Radford University, Radford (USA)

This study examines the bibliometrics of the controversial scientific literature of Polywater research, focusing on publication types (books, journal publications, conference proceedings, and technical reports). Publication (P) frequency is used to measure publication "shape" or pattern and output, citations per publication (CPP) for impact, author self-citations (SC) and uncited publications (UP) for their effect on P and CPP. Findings show an epidemic publication pattern, journal publications with the highest P, books with the highest CPP, and insignificant SC and UP. Comparisons to several non-controversial scientific literatures suggest that these findings may be common to other controversial scientific literatures.

Introduction

Periodically throughout the history of science, a discovery is reported that creates a scientific controversy. If the discovery is confirmed, then a new field or research specialty is created, often with an accompanying journal (or two). If the discovery is not confirmed or replicated, then interest dies out, creating no lasting specialty or research area. Since the main product of scientific research is the publication, the by-product of a controversial discovery is a related literature (hereafter *controversial scientific literature*) composed of publications generated by researchers trying to prove (or disprove) the controversial claim. What do the bibliometrics of a controversial literature look like? How does it differ from a normal (or *non-controversial)* scientific literature? This study is an attempt to answer this question by examining the bibliometrics of a literature created by the reported discovery of a new kind of water, polymerized (or polymer) water, commonly known as Polywater (FRANKS, 1981). As a case study, the Polywater research literature has the advantage of having a definite time frame, beginning in 1962 with the publication of a series of papers by FEDYAKIN (1962a,b) and DERYAGIN & FEDYAKIN (1962a,b), and ending in 1974 with the publication of the last Polywater papers, and it is not too large to examine the entire literature rather than a

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Address for correspondence:
ERIC ACKERMANN
McConnell Library, Radford University, Radford, VA, 24142 USA
E-mail: egackerma@radford.edu

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sampling of it. Of particular interest is the dynamics of the Polywater literature over time, in terms of its publication and citation patterns for both the literature as a whole as well as for its constituent parts or publications types. Also examined are the effects on these dynamics of the presence in the data of author self-citations and uncited publications.

Terminology

Bibliometrics is the quantitative analysis of a literature (SELF et al., 1989), usually based on its publication and citation data. A *literature* is the sum of the printed publications of a research field or specialty, and can include both the traditional formal, scholarly publications, such as journals, books, and monographs, and the informal, more ephemeral forms of communication, such as conference proceedings and technical reports, known as the *grey literature* (TABAH, 1995b; PELZER & WIESE, 2003; DIODATO, 1990). The grey literature is often difficult to find and access, accounting for its relatively low citation rate. For example, OSEMAN (1988) reports an average citation rate for conference papers of 1.5, while PELZER & WIESE (2003) notes the grey literature accounts for only 6.38% of the total citations received by core veterinary medicine journals.

A scientific literature is often associated with a *research field* (or *specialty*), which is a unit smaller than a discipline, composed of a group of scientists often from the same discipline who conduct research along similar lines (DE MAY, 1992; HAGSTROM, 1970). Specialties can be difficult to define however (HAGSTROM, 1970; DE MAY, 1992) and their boundaries change over time as scientists shift their primary research efforts from one specialty to another, or participate in research projects involving multiple specialties, or both (HAGSTROM, 1970). A way to define the boundaries of a research field is through the compilation of a bibliography of its literature (DE MAY, 1991).

A literature is made up of *publication types.* For this study there are four publication types. *Books* are authored books and monographs as well as chapters in edited books and monographs. Books do not seem to have the location and accession problems reported for the grey literature. They do however tend share a similar low publication presence in the scientific literature reflecting their secondary role as a means of communication in the sciences (HAGSTROM, 1970; MEADOWS, 1998). *Journal publications* are research articles, reviews, notes, and letters that report original research and are published in scholarly, peer reviewed or refereed journals. They are the primary means of formal communication in the sciences. *Conference proceedings* are publications composed of papers presented at a given conference or symposium that are subsequently published together in a single publication. *Technical reports* are publications of scientific work done by academic, government, or industry organizations.

Publications can be cited. A *cited publication* is one that received at least one citation in the reference list of a subsequent publication, whereas an *uncited publication* did not. Some of the citations received can be author self-citations. An *author self-citation* (or just *self-citation* hereafter) is a "citation given in a publication of which at least one author (either first author or co-author) is also an author of the cited paper" (VAN RAAN & VAN LEUWEN, 2002, p. 616). DE MAY (1992) reports a higher than normal rate of author self-citations in fast growing literatures, as does BUDD & HURT (1991) for the Superstring theory literature, and in the first few years after publication (ASKNES, 2003), as MEADOWS & O'CONNOR (1971) report for the first year of Pulsar research. In contrast, other investigators expect to find a lower than usual level of self-citation rate in a new research field such as Polywater. PICHAPPAN & SARASVADY (2001) for instance argue that this is due to the association of self-citations with an author's longevity in a research field, and are indicative of the cumulative growth of scientific knowledge, with research building on itself (see also BONZI & SYNDER, 1991). Moreover, the motives for self-citation do not vary appreciably from those for citations to others (BONZI & SYNDER, 1991), thereby reducing the concern that it is mainly the by-product of excessive authorial ego (ASKNES, 2003). Other investigators such as ASKNES (2003) find self-citations problematic because they do not show how much a publication influences or impacts future scientific research, which is a basic assumption of citation analysis (MARTIN & IRVINE, 1983; MOED et al., 1995.)

It is important to note at this point what this study is *not*. It is not a history of Polywater research and the controversy that surrounded it, which is admirably covered by FRANKS (1981). It is not an evaluation or an assessment of the various truth claims made by the participants in that controversy. Nor is this study concerned with examining the existence and nature of pathological science, or its applicability to the Polywater phenomena.

Background

While a history of Polywater is beyond the scope of this paper, a very brief summary of events, drawn from FRANKS (1981), is provided to give some context for the reader unfamiliar with the controversy. The Soviet scientist N. N. FEDYAKIN (1962a) reported the discovery of Polywater (also known as anomalous water or modified water) in 1962, after observing the unusual capillary activity of a bound water sample while studying the behavior of thin films of water in contact with solid surfaces. His research was soon taken over, developed, and later championed by another Soviet scientist B. V. Deryagin (1962a). Through a combination of publication in mainly non-English language journals (though English translations were available, e.g., FEDYAKIN (1962b) and DERYAGIN & FEDYAKIN (1962b)), differences in experimental technique, and Cold War Era politics, Polywater received scant attention by Western science, even

after Deryagin's participation in the prestigious 1966 Faraday Society Discussions in Great Britain and the 1967 Gordon Research Conference in the United States. This all changed in 1969 with the publication in *Science* of LIPPINCOTT et al.'s (1969) reported spectroscopic confirmation, which triggered an explosion of experimental research and theoretical speculation. Supporters claimed that Polywater was a new form of water possessing a unique structure and semi-solid characteristics. Detractors maintained that these features were not unique, but merely a product of silicon or other impurities in the experimental sample. Skepticism grew over the validity of the Polywater claims, as an increasing number of researchers were unable to replicate or create their own samples of the substance. The controversy continued until 1973 when DERYAGIN & CHURAEV (1973) published a re-evaluation in *Nature*, stating that the original findings were due to silicate impurities in the sample, not to the existence of Polywater. The last Polywater publications appeared in 1974, due mainly to the delay between the submission and publication of scholarly papers.

Literature review

Polywater literature

Relatively little is written about the Polywater controversy in general, and of that, even less about its communication or publishing patterns. The two main sources are FRANKS' (1981) excellent book and an article by BENNION & NEUTON (1976). FRANKS (1981) analyzes the communication patterns of the Polywater journal literature as part of his in-depth study of the controversy. He reports no unusual author self-citation rate, nor comments on the presence or absence of uncited publications in the Polywater literature. Franks is struck however by the abnormally prolific or epidemic pattern of publication sparked by the discovery of Polywater. An *epidemic publication pattern* is created by a scientific discovery or theory that diffuses so rapidly through a literature during a given period of time that it mimics the epidemic spread of a disease (SELF et al., 1989; TABAH, 1995a,b; DUFOUR & TABAH, 1998). It produces a characteristic surge and decline or spike in rate of publication in a literature. BENNION & NEUTON (1976) reported an epidemic growth pattern for the Polywater journal literature, similar to the one described by FRANKS (1981, see especially Figure 9, p. 120 and Figure 10, p. 128).

Bibliometric studies of other literatures

The literature review focused on looking for bibliometric studies of the literature of other non-controversial scientific research specialties that include a yearly analysis of the publication and citation data of the constituent publication types. The goal was to obtain data from these studies to create a comparative context for the findings of this

study in the form of yearly publication patterns, citations per paper (CPP), as well as the number of author self-citations (SC) and uncited publications (UP) for each of the four publication types (books, journal publications, conference proceedings, and technical reports). Unfortunately, none of the studies examined (hereafter *literature review study* or *studies*) fit all these criteria. There are however bibliometric studies that contained some or most of the desired criteria.

An analysis of the publication data by publication type is included in four studies: LAWSON et al.'s (1980) study of the energy analysis field, CZERWON's (1990) study of Monte Carlo/lattice field theory in high energy physics, DIODATO's (1991) study of the Supernova 1987A literature, and TSAY et al.'s (2000) study of the semiconductor field. The first three studies include yearly breakdowns of publication frequency, while the fourth provides only aggregate data for the entire study period. The time frame for each of the first three studies above is different, thereby precluding any year-by-year comparison of publication frequencies for each publication type. Instead, the publication types will be compared across studies by converting the publication frequencies to percentages, averaged yearly as well as for the entire time period of each study (see Table 1).

Table 1. Summary of the percentage of publication frequency for each publication type in the literature review studies

Literature Review Studies	Publication Type							
	Journal				Conference			
	Books		Publications		Reports		Technical Reports	
	%Avg	%APY	%Avg	%APY	%Avg	%APY	%Avg	%APY
Semiconductors, 1978–1997 (TSAY et al., 2000)	0.002	0.0001	0.67	0.035	0.33	0.017	0.001	0.00005
Monte Carlo/ lattice field theory, 1979–1984 (CZERWON, 1990)	*	*	0.76	0.109	*	*	*	*
Energy analysis, 1968–1977 (LAWSON et al.,1980)	0.05	0.005	0.48	0.048	0.19	0.019	0.27	0.027
Supernova 1987A, 1987–1989 (DIODATO, 1990)	0.007	0.0023	0.67	0.22	0.29	0.097	0.03	0.01
Total	0.06	0.0074	2.58	0.412	0.81	0.133	0.30	0.037
Average	0.02	0.0025	0.65	0.103	0.27	0.044	0.10	0.012

Notes: %Avg = average percentage for the entire time period of the study.
%APY = average percentage per year.
* excluding non-journal publications from CZERWON (1990) which are grouped together into one category in the study, with %Avg = 0.24 and %APY = 0.034.

No bibliometric studies of research specialties found included a yearly citation analysis for all publication types. Nine studies were found that included citation analysis of the journal publications either using citation per publication (CPP) or providing frequency data from which it can be calculated (see Table 2). Of the nine, seven studies also provide citation data for author self-citations, while eight of the nine studies provide uncited publication data. There are some limitations to consider however. The time frames of the studies vary from two to eleven years, the citation windows include both fixed (two- to five-year) and cumulative, and the citation data for five of the nine studies is restricted to national (e.g., Dutch) journal output. As with the publication type analysis above, this means that yearly comparisons are not feasible. Instead, with the exception of the citations per year data, the self-citations and uncited publications will be compared across studies by converting the frequency data to percentages, averaged yearly as well as for the whole time period.

Table 2. Summary of citations per paper (CPP), percent author self-citations (%SC), and percent uncited publications (%UP) for each research specialty or field in the literature review

		%SC		%UP	
Literature Review Study	CPP	%Avg	%APY	%Avg	%APY
Dutch condensed matter physics, 1985–1994 (RINIA et al., 1998)	8.80	0.27	0.027	0.28	0.028
Dutch applied nutrition and food research, 1990–1996 (VAN RAAN & VAN LEEUWEN, 2002)	3.11	0.36	0.051	0.36	0.051
Dutch academic chemical research 1980–1991 (MOED & HESSELINK, 1996)	12.20	0.29	0.024	0.17	0.014
Dutch environmental medicine, 1995–1998 (VAN RAAN et al., 2001)	3.49	0.32	0.080	0.38	0.095
Dye laser research, 1966–1972 (MAGYAR, 1974)	5.00	0.20	0.028	0.21	0.030
Dutch nucleic acid research 1980–1991 (MOED et al., 1995)	20.90	0.22	0.018	0.13	0.011
Pulsar research, 1968–1969 (MEADOWS & O'CONNOR, 1971)	8.50	0.13	0.065	NA	NA
Monte Carlo/lattice field theory, 1979–1985 (CZERWON, 1990)	15.90	NA	NA	0.11	0.016
PCD/apoptosis, 1981–1996 (GARFIELD & MELINO, 1997)	13.50	NA	NA	0.48	0.030
Total	91.40	1.78	0.293	2.13	0.275
Average	10.16	0.25	0.042	0.27	0.034

Notes: %Avg = average percentage for the entire time period of the study.
%APY = average percentage per year.
NA = data not available or reported.

These comparative results should be treated with caution. They are only approximations designed to give some sense of how the findings of this study fit into the existing knowledge, and how generalizable (or not) the findings may be to the literatures of other scientific specialties.

Methods

Data set

The source of publication date is the *Composite Bibliography of Polywater Research Literature, 1962–1974* (hereafter *Polywater bibliography*) (ACKERMANN, 2003). The level of analysis is the Polywater research literature as defined by the Polywater bibliography (ACKERMANN, 2003). The unit of analysis is the publication type, previously defined, and also drawn from the Polywater bibliography (ACKERMANN, 2003). The Polywater bibliography (ACKERMANN, 2003) is an unpublished publication/article level work compiled by the author and based on GINGOLD's (1973) extensive review article, augmented where needed by publications listed in ALLEN (1971), PRION (1973), LEHMANN (1975), and HISTCITE™ 2003). Duplicate entries, works from the popular press (newspapers and magazines), and popular science magazines are excluded.

Using a bibliography to define the level of analysis for this study has several advantages. The component parts were each developed by an expert or practicing scientist in the field. This bestows a certain amount of validity on the items included and hence the definition or delineation of the boundaries of the Polywater specialty used for this study (DE MAY, 1992). Defining the boundaries in the literature can be a problem, as it tends to be a combination core and dispersed literature (DE MAY, 1992; PRICE, 1970). While it can be relatively easy to find the key publications for an emerging specialty, it can be difficult to determine which fringe publications belong to it. Different bibliographies of the same specialty can yield different literature sets, which can overlap at the core but have different compositions at the dispersed margins (DE MAY, 1992). This ambiguity can be minimized however by merging the results of several bibliographies and eliminating any overlapping coverage. Hence the construction of the Polywater bibliography (ACKERMANN, 2003) from five overlapping sources (GINGOLD, 1973; ALLEN, 1971; PRION, 1973; LEHMANN, 1975; HISTCITE, 2003), and its subsequent utility in defining the research field and literature of this study.

The citation source will be the print version of the Science Citation Index (SCI) Five and Ten Year Cumulations for 1955–1964, 1965–1969, 1970–1974, and 1975–1979 (INSTITUTE FOR SCIENTIFIC INFORMATION, INC., 1971, 1976, 1981, 1984). It is worth noting that the SCI contains citation data for publication types other than journal

publications. One can look up the author of a journal publication for a given year and often discover citation data for non-journal materials such as technical reports, books, and conference proceedings.

Metrics

In this study, both the Polywater literature as a whole as well as its publication types will be analyzed using a series of metrics based on those developed to evaluate science and technology research activity (MARTIN, 1996; MARTIN & IRVINE, 1983; NOYONS et al., 1998; MOED et al., 1995), modified as defined below.

Literature metrics. These metrics are designed to measure certain aspects of the Polywater literature as a whole. Several of the metrics will also be used to compare certain aspects of the Polywater literature with the literature review studies, and will be annotated accordingly.

1. Publication (P) frequency. A measure of scientific productivity (MARTIN, 1996), it is also the basic component or building block of a literature. Without P there can be no publication data, nothing to attract or receive citations, nor any bibliometric data to analyze. An analysis of the pattern of P over time can provide the shape or "footprint" of a literature as well.

2. Citation (C) frequency. It measures the general impact or influence of a research field or specialty (MARTIN, 1996; MOED et al., 1995). In this study, it will be used primarily in the calculation of the citations per publication (CPP) metric (see below).

3. Citations (C) per publication (P) or CPP. It measures the impact or influence of a research field or specialty, normalized for the differing size of output, allowing the fair comparison of literatures of disparate sizes (MARTIN, 1996). Therefore, this metric will be used to compare the Polywater journal literature with the literature review studies. The metric is calculated by dividing C by P or C/P.

4. Author self-citation (SC) frequency. It measures the number of self-citations received and therefore having no influence or impact on the literature. The SC frequencies will be converted to %SC to facilitate the comparison of the values from the Polywater literature with similar data from the literature review studies.

5. Uncited publication (UP) frequency. It measures the number of publications not cited and therefore having no influence or impact on the literature. The UP frequencies will be converted to %UP to facilitate the comparison of the values from the Polywater literature with similar data from the literature review studies.

Metrics of publication types. These metrics will be used to analyze the component parts of the Polywater literature, the publication types. Publication type metrics are the literature metrics modified to reflect the data for each publication type (see Table 3). Certain of these metrics will be used to compare the publication types with their counterparts in the literature review studies.

Table 3. Metrics for publication types in the Polywater literature, 1962–1974

Literature Metric	Publication Type			
	Books (b)	Journal Publications (j)	Conference Proceedings (c)	Technical Reports (t)
Publications (P)	Pb	Pj	Pc	Pt
Citations (C)	Cb	Cj	Cc	Ct
Citations per Publication (CPP)	CPPb	CPPj	CPPc	CPPt
Author Self-Citations (SC)	SCb	SCj	SCc	SCt
Uncited Publications (UP)	UPb	UPj	UPc	UPt

Data collection

The citations to the publications found in the Polywater bibliography (ACKERMANN, 2003) were manually retrieved from the print versions of the SCI, mentioned above (INSTITUTE FOR SCIENTIFIC INFORMATION, INC., 1971, 1976, 1981, 1984). A five-year, fixed citation window was used (see below). Journals names covered by the SCI are recorded by their SCI abbreviations, and any inconsistent abbreviations standardized. Other journal names remain as they appeared in the Polywater bibliography (ACKERMANN, 2003). Spellings of names are standardized as well, as several of the Russian authors are listed in the SCI using variant spellings, such as Deryagin, Derjaguin, Dervagin and Churayev, Churaev. Papers published both in original journal and in translation journal (e.g., KOLL ZH, and COLLOID J) are treated as separate documents, each with their own publication history.

Citation windows. A *fixed citation window* provides an equal time period from the date of publication for each publication to receive citations. Fixed citation windows are particularly useful for data aggregated below the national level and not counted yearly, "based on relatively small publication numbers", and that displays "considerable volatility". (BUTLER, 2001, p. 96). A two-year fixed citation window favors " 'rapid response' disciplines" that publish in journals with short citation half-life. A five year fixed citation window is "often used in bibliometric studies", falling between short- and "long-term assessment", while still being long-term enough to allow any "distinct polarization pattern" to develop in the data due to the variation in citedness. (AKSNES & SIVERTSEN, 2001, p. 24). AVERSA (1985) noted that in general the citation rate for papers found in the SCI tended to peak at four years after the date of publication. A relatively short citation window (e.g., three years) tends to produce a higher self-citation rate than a longer one (e.g., five years) (AKSNES, 2003). For this study then, a five year, fixed citation window will be used. The *five-year citation window* is the year of publication plus four years. Any author self-citations are collected for separate analysis.

Data analysis methods

Data analysis will be confined to use of descriptive statistics and the presentation of data into tables and charts.

Findings

Polywater literature

The overall footprint or shape of the Polywater literature is one of a delayed epidemic growth pattern. The literature gradually builds from 1962 to 1968, the rising fast to peak in 1970, then rapidly declines to pre-epidemic size in 1974, dying out altogether by 1975 (see Figure 1). The main area of epidemic growth is in the years 1969–1972. This finding conforms closely to the work of FRANKS (1981) and BENNION & NEUTON (1976).

Publication frequency (P) per publication type is dominated for the entire study period by Pj, which comprise 83% of the total publications making up the Polywater literature (see Figure 1 and Table 4). The Pb frequency is a distant second with 08% of the total publications, followed by Pt with 07%, and finally Pc with 02%. While the journal publications are present throughout the literature (except for 1963–1964), books appear sporadically in 1964, 1966, and 1967, but are not consistently present until 1969.

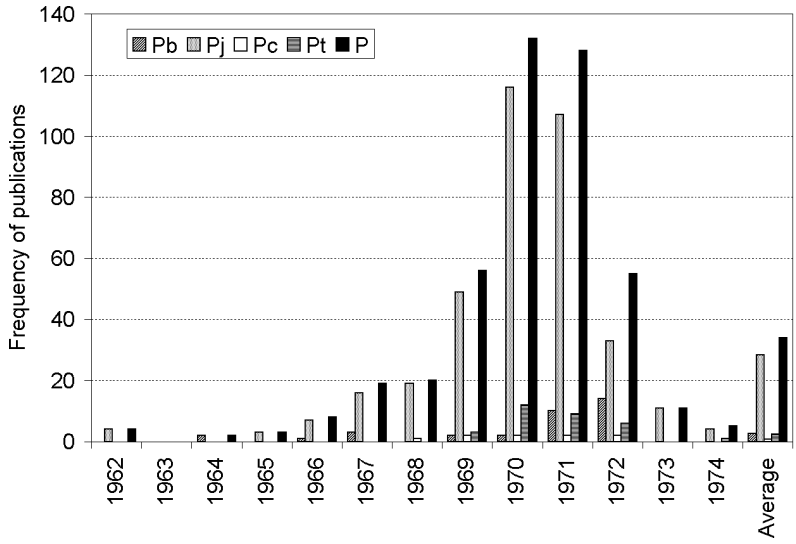

Figure 1. Frequency of publications (P) per publication type in the Polywater literature, 1962–1974

Table 4. Frequency of publications (P), citations (C), and citations per publication (CPP) for each publication type in the Polywater literature, 1962–1974

Year	Publication type												Total		
	Books			Journal Publications			Conference Proceedings			Technical Reports					
	Pb	Cb	CPPb	Pj	Cj	CPPj	Pc	Cc	CPPc	Pt	Ct	CPPt	P	C	CPP
1962	0	0	0	4	12	3.00	0	0	0	0	0	0	4	12	3
1963	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1964	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0
1965	0	0	0	3	19	6.33	0	0	0	0	0	0	3	19	6.33
1966	1	8	8.00	7	83	11.86	0	0	0	0	0	0	8	91	11.38
1967	3	3	1.00	16	145	9.06	0	0	0	0	0	0	19	148	7.79
1968	0	0	0	19	204	10.73	1	2	2.00	0	0	0	20	206	10.30
1969	2	43	21.50	49	577	11.78	2	3	1.50	3	3	1.00	56	626	11.18
1970	2	10	5.00	116	1087	9.37	2	3	1.50	12	17	1.42	132	1117	8.46
1971	10	189	18.90	107	499	4.66	2	2	1.00	9	9	1.00	128	699	5.46
1972	14	262	18.71	33	356	10.79	2	2	1.00	6	10	1.67	55	630	11.45
1973	0	0	0	11	104	9.45	0	0	0	0	0	0	11	104	9.45
1974	0	0	0	4	29	7.25	0	0	0	1	1	1.00	5	30	6.00
Total	34	515	NA	369	3115	NA	9	12	NA	31	40	NA	443	3682	NA
%Total	0.08	0.14	NA	0.83	0.85	NA	0.02	0.003	NA	0.07	0.01	NA	1.00	1.00	NA
Average	2.62	39.62	15.12	28.38	239.62	8.44	0.69	0.92	1.33	2.38	3.07	1.29	34.07	283.23	8.31

Notes: NA = not applicable.

Sources: ACKERMANN (2003), INSTITUTE FOR SCIENTIFIC INFORMATION, INC. (1971, 1976, 1981, 1984).

Table 5. Frequency of author self-citations (SC) and uncited publications (UP) for each publication type in the Polywater literature, 1962–1974

Year	Publication Type								Total	
	Books		Journal Publications		Conference Proceedings		Technical Reports			
	SCb	UPb	SCj	UPj	SCc	UPc	SCt	UPt	SC	UP
1962	0	0	3	2	0	0	0	0	3	2
1963	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0
1965	0	0	9	2	0	0	0	0	9	2
1966	1	0	19	2	0	0	0	0	20	2
1967	0	1	29	1	0	0	0	0	29	2
1968	0	0	29	2	0	0	0	0	29	2
1969	4	0	37	1	0	0	0	1	41	2
1970	0	0	87	2	1	0	1	0	89	2
1971	8	0	33	1	0	0	0	1	41	2
1972	9	0	16	0	0	0	0	0	25	0
1973	0	0	11	1	0	0	0	0	11	1
1974	0	0	3	1	0	0	0	0	3	1
Total	22	1	276	15	1	0	1	2	300	18
%Total	0.01	0.002	0.07	0.03	0.0003	0	0.0003	0.01	0.08	0.04
Average	1.69	0.08	21.23	1.15	0.08	0	0.08	0.15	23.08	1.38

Sources: ACKERMANN (2003), INSTITUTE FOR SCIENTIFIC INFORMATION, INC. (1971, 1976, 1981, 1984)

From 1969 they grow steadily in frequency until peaking at 1972, the last year they appear. Technical reports appear first in 1969, peaking in frequency in 1970, then gradually declining until 1972, the last year of their appearance. Conference proceedings appear first in 1968 and maintain a steady presence until 1972, their last year.

An examination of the frequency of CPP per publication type presents a marked contrast to the frequency pattern of P above, especially in the main epidemic years of 1969–1972 (see Figure 2 and Table 4). Though CPPj is still dominant for ten of the thirteen years of the study, CPPb is a close second in 1966, and dominates three of the four main epidemic years, 1969, 1970, and 1971, as well as the average for overall literature. The frequencies for CPPt and CPPc shows a similar pattern to their analogs Pt and Pc, with the exception that CPPt rallies to its highest value in 1972 instead of 1970.

The frequency of SC generally follows the growth and decline pattern for C, but with much lower presence, ranging on average from 0.003% of the total C for SCc and SCt to 01% for SCb and 07% for SCj (see Figure 3 and Table 5). The frequencies for SCb, SCc, and SCt are irregular and sporadic, exhibiting no yearly pattern. Only SCj shows a yearly pattern, almost bell-curved in shape, rising gradually from nine self-citations in 1965 to thirty-seven in 1969, suddenly rising to a peak of eighty-seven in 1970, only to fall sharply to 33 in 1971, then gradually fading away to three in 1974.

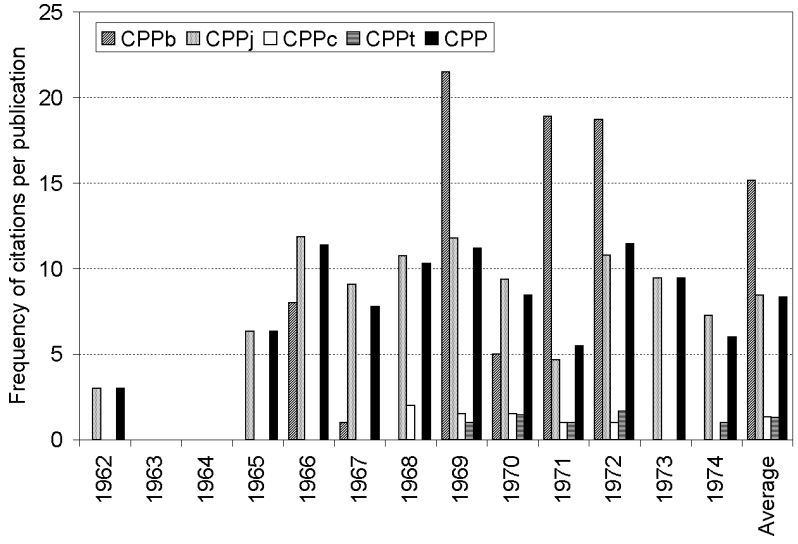

Figure 2. Frequency of citations per publication (CPP) for each publication type in the Polywater literature, 1962–1974

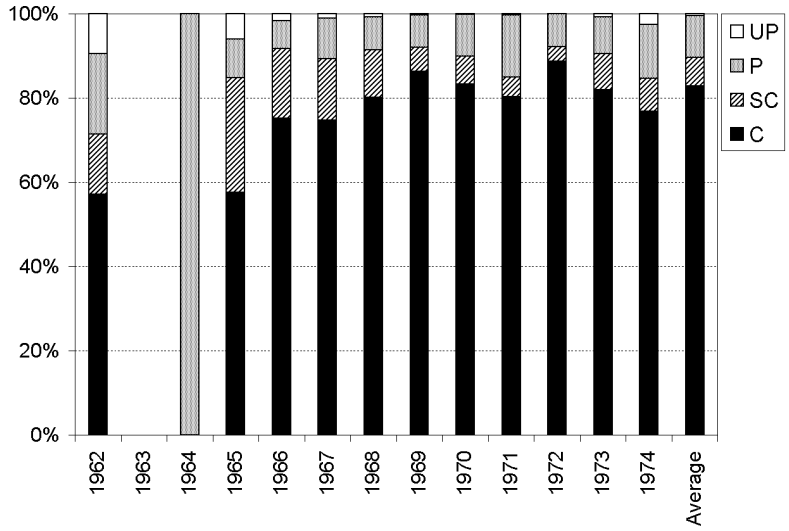

Figure 3. Relative proportions of citations (C), author self-citations (SC), publications (P), and uncited publications (UP) in the Polywater literature, 1962–1974

The frequency pattern for UP is very steady and flat overall, as is that for UPj (see Figure 3 and Table 5). On the other hand, with average values ranging from 0% of the total P for UPc to 0.02% for UPb to 1% for UPt to 3% for UPj, their frequency patterns are similar to those of their respective self-citation analogs: irregular and sporadic, exhibiting no yearly pattern.

Comparison with literature review studies

The overall and yearly average %Pb for the Polywater literature is significantly higher than that of the literature review studies, +60% and +41% respectively (see Table 6). The Polywater %Pj is split, with the overall average +12% while the yearly average is –23% that of the literature review studies. The %Pc shows the greatest difference between the Polywater literature and the literature review studies, the former averaging –86% lower overall and –95% lower yearly. The difference in %Pt is not quite so severe, with the Polywater literature lower than the literature review studies in both averages by –18% overall and –41% yearly respectively.

The CPPj for the Polywater literature is only 9% lower than the value for the literature review studies (see Table 7). However, Polywater's average %SCj is significantly lower vis-à-vis the literature review studies, –56% overall and –79%

yearly. The average %UP is drastically lower for the Polywater literature than for the literature review studies, –80% overall and –89% annually.

Table 6. Comparison of the average percentage publication frequency (%P) of each publication type for the Polywater literature and the literature review studies

Study	Publication Types							
	Books (%Pb)		Journal Publications (%Pj)		Conference Proceedings (%Pc)		Technical Reports (%Pt)	
	%Avg	%APY	%Avg	%APY	%Avg	%APY	%Avg	%APY
Polywater Literature	0.08	0.006	0.83	0.064	0.02	0.0015	0.07	0.005
Literature Review Studies	0.02	0.0025	0.65	0.103	0.27	0.044	0.10	0.012
Difference (Polywater-Literature Review Studies)	+0.06	+0.0035	+0.18	–0.039	–0.25	–0.043	–0.03	–0.007
% Difference	+60%	+41%	+12%	–23%	–86%	–95%	–18%	–41%

Notes: %Avg = average percentage for the entire time period of the study.
%APY = average percentage per year.

Table 7. Comparison of the average citations per publication (CPPj), percent self-citations (%SCj), and percent uncited publications (%UPj) for the journal publications in the Polywater literature and the literature review studies

Study	CPPj	%SCj		%UPj	
		%Avg	%APY	%Avg	%APY
Polywater Journal Publications	8.44	0.07	0.005	0.03	0.002
Literature Review Studies' Journal Publications	10.16	0.25	0.042	0.27	0.034
Difference (Polywater-Literature Review Studies)	–1.72	–0.18	–0.037	–0.24	–0.032
% Difference	–9%	–56%	–79%	–80%	–89%

Notes: %Avg = average percentage for the entire time period of the study.
%APY = average percentage per year.

Discussion

Polywater literature

The epidemic publication shape of the overall Polywater literature is very similar to that reported by FRANKS (1981) and BENNION & NEUTON (1976). The CPP pattern for both the overall Polywater literature and each publication type does not show a similar

pattern. The significance of this discrepancy is not yet clear. It could be related to the choice of metrics. Perhaps bibliometric measures developed for use in the evaluation of research units are not necessarily ones appropriate for analyzing literatures exhibiting an epidemic component.

The high CPPb values for the epidemic years and overall point to an important role for books in scientific literatures normally held for journal publications (MEADOWS, 1998). Relying only on Pj would have missed this finding. For a controversial literature such as Polywater, it may also reflect researchers falling back on the archival or foundational knowledge found in the books of the closest related discipline to help them understand a new and previously unknown phenomenon. This assumes that books function as the repository of codified disciplinary knowledge in the sciences.

The numbers of SC and UP, both overall and for each publication type, are too small relative to C and P respectively to have any significant effect on P and CPP as metrics. Hence, they can be safely ignored and left in the data in any future bibliometric analyses of the Polywater literature. The low SC values both overall and by publication type may be due to the newness of the Polywater field, and its lack of a pre-existing body of literature by a researcher in an older, more established field (PICHAPPAN & SARASVADY, 2001; BONZI & SYNDER, 1991.) The lack of an established deep or extensive literature may also account for the very low UP values. With little available literature to draw on, every available publication is pressed into service as quickly as it is produced.

Comparison with literature review studies

The findings from the comparison of the Polywater literature and literature review studies support the relevant aspects of the findings for the Polywater literature itself. The importance of books, reduced importance of journal publications (both Pj and CPPj), low reliance on conference proceedings and technical reports is reflective more of the Polywater literature than of the literature review studies. The Polywater literature also exhibits a much lower rate of author self-citations and uncited publications than does the literature review studies.

Conclusions and recommendations

The use of a composite bibliography to define the limits of the Polywater research field and its literature proved very useful. It not only identifies the core materials, usually journal publications, but also provides valuable information about other significant publications such as books, conference proceedings, and technical reports easy to overlook if one relied mainly on the SCI for bibliometric data. The use of

overlapping source documents authored by experts in the field provides a greater degree of accuracy and validity to the publications selected for inclusion in the bibliography. It is however time consuming to track down and merge the results of review articles and bibliographies for a given research field. Also, how many such source documents are required before one can be confident that the core and most important non-core publications are discovered? Perhaps the answer lies in validity studies, in which researchers who are experts in the field evaluate scope and content of a composite bibliography of their research specialty.

The comparison of the publication types for Polywater literature and literature review studies indicates the presence of findings potentially generalizable beyond the Polywater literature to other controversial literatures. These findings suggest a strong reliance on the foundational knowledge by researchers when faced by a new, controversial discovery, which is reflected in its literature by a high P for books. The reliance on journal publications is still strong, but less so than in non-controversial literatures. The role of conference proceedings and technical reports is much less significant in controversial than non-controversial literatures.

The impact of journal publications (CPPj) is slightly less in controversial literatures, reflecting its somewhat reduce role. The effect of the number author self-citations and uncited publications on the impact of journal publications (both Cj and CPPj) are negligible in controversial literatures. This alleviates the concern of those bibliometric researchers who are concerned with their effect on citation metrics (ASKNES, 2003). It also suggests that the timeframe available for the development of controversial literatures is too short for researchers to create enough of their own research to cite later (PICHAPPAN & SARASVADY, 2001; BONZI & SYNDER, 1991), as well as a strong need to utilize all available journal publications as so few exist.

Currently, these generalizations about controversial literatures remain tentative, based on a limited amount of data. To improve the situation, more bibliometric studies are needed of the literatures of controversial scientific discoveries as well as of their non-controversial counterparts that include non-journal publications such as books, conference papers, and technical reports. It is also not entirely clear that the metrics developed for the bibliometric evaluation of research units is entirely appropriate for the study of the literature dynamics of controversial science. New metrics may be needed to capture these dynamics. The role and relative importance of non-journal publications types in the bibliometric dynamics of these literatures is poorly known and understood. More work is needed in this area as well.

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