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Use of citation per publication as an indicator to evaluate pentachlorophenol research

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The objective of the study was to perform a bibliometric analysis of all pentachlorophenol-related publications in the Science Citation Index (SCI). Analyzed parameters included document type, language of publication, page count, publication output, authorship, keywords plus, publication pattern, citation and country of publication. The US produced 29% of the total single country publications where the seven major industrial countries accounted for the majority of the total production (66%). An indicator citation per publication was successfully applied in this study to evaluate the impact of number of authors, countries, and journals. The mean value of citation per publication of collaborative papers was higher than that of single country publications. In addition analysis of keywords plus in different period was applied to indicate a research trend.

Introduction

Pentachlorophenol (PCP) is a xenobiotic compound and toxic to all forms of life. Since its introduction around 1930, PCP has been widely used as a wood preservative, and also as a pesticide (herbicide, fungicide, insecticide and mollusicide), disinfectant and bactericide [KIEFER & AL., 1998]. In May 1997, the US Environmental Protection Agency (EPA) noted 59 sites polluted by PCP in the USA [ENGWALL & AL., 1999].

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In the contaminated area, PCP was detected not only in the water and soil, but also in the body of organisms. PCP was found to be the dominant phenolic compound in whole blood from Inuit [SANDAU & AL., 2000] and Latvian and Swedish fish eaters [SJODIN & AL., 2000]. The absorbed PCP can be stored in liver [CHHABRA & AL., 1999]. It has also found that PCP could effectively interfere with the binding of physiological ligands to steroid receptors and binding proteins [DANZO, 1997], which may disturb the endocrine system, affected immune function, and inhibit reproduction and development [DIMICH & AL., 1996]. Considering the character of high toxicity, long persistence and recalcitrant to degrade, PCP has become a kind of conspicuous environmental pollutant and was included in the list of priority pollutant and forbid to use by the USEPA [US ENVIRONMENTAL PROTECTION AGENCY, 1980].

Our purpose was to study the pentachlorophenol research performance based on 1,852 papers published in Science Citation Index (SCI)-indexed periodicals between 1994 and 2005. These documents were analyzed and evaluated in order to determine the quantitative characteristics of pentachlorophenol research. In this study, except for traditional indicator, an indicator named citation per publication (CPP) was presented to compare impact of a publication in different analysis.

Materials and methods

Documents used in this study were based on the database of the SCI subscribed for ISI Web of Science, Philadelphia, PA, USA. 'Pentachlorophenol' was used as keywords to search titles, abstracts, or keywords. Articles origination from England, Scotland, Northern Ireland, and Wales were grouped under the UK heading. The impact factor of a journal was determined for each document as reported in the JCR 2005. Collaboration type was determined by the address of each author, where 'independent' was assigned if no collaboration was presented. 'International collaboration' was assigned if the paper was cosigned by researchers from more than one country.

The impact of a publication is assessed in terms of the number of citations that it has received relatively to other outputs in the journal. However, the numbers of times cited for an article is highly correlated with the length of time since its publication. Figure 1 shows the relationship between the average number of times cited per paper and the number of years since its publication. It shows that the frequency of being cited was highest in the 4^{th} full year since its publication, and began to decrease thereafter. Because the 2^{nd} citations per paper were close to the 4^{th}, we can exchange them to obtain more data. Let P indicates total number of publications and C indicates the number of total citations for the first 3 years since the articles were published (including published year). The average first 3 year citations per publication (CPP) are defined as the total citations over total publications to produce a value for the average citation for the first 3 years per publication produced. Therefore, when CPP is reported, we only

analyzed the documents published in the period from 1994 to 2003 because paper published in 2004 and 2005 do not accumulate 3 full year citation records thus were excluded from the analysis.

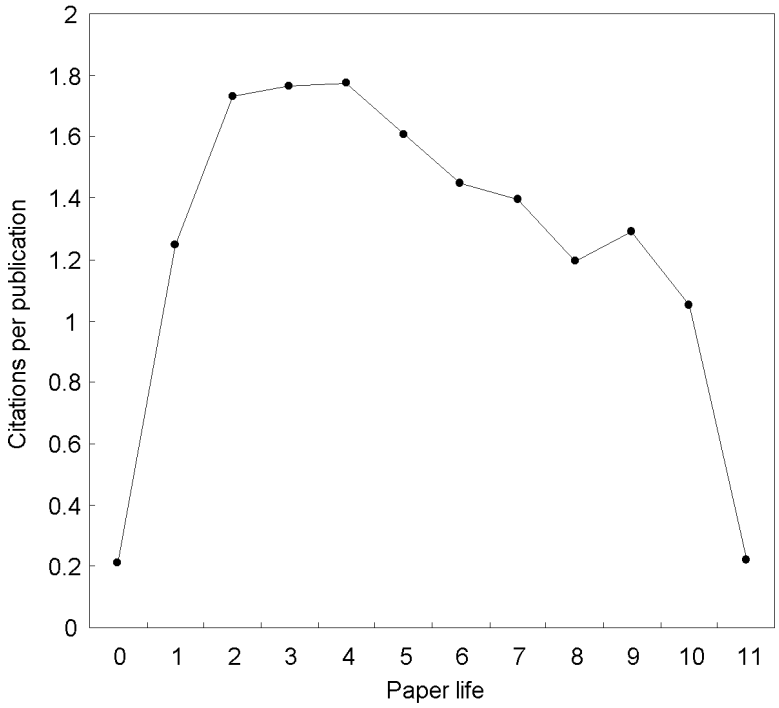

Figure 1. Citation history of the pentachlorophenol papers

Results and discussion

Documents were analyzed according to their type, language of publication, page count, publication output, authorship, keywords plus, publication pattern, citation and country of publication.

Type of document

The total papers related to PCP research in ISI web database from 1994 to 2005 are 1,852. From the distribution analysis, 9 document types were found. The paper article

was the most frequently used document type comprising 95% of the total productions, followed by review (42, 2.3%), meeting abstract (30, 1.6%), letter (5, 0.27%), note (5, 0.27%), and only 1 for correction, correction addition, discussion, editorial material respectively. Consider citation per publication as an indicator for papers were published from 1994 to 2003, review paper had the highest value of CPP (4.1), followed by note with 3.6 CPP, and article with 3.2 CPP.

Language of publication

Language analysis showed 1,816 papers (98%) were published in English, followed distantly by German (17, 0.92%), Japanese (6, 0.32%), Chinese (4, 0.22%), French (4, 0.22%), Czech (2, 0.11%), Polish (2, 0.11%), and Portuguese (1, 0.054%). That showed English was the most dominating language.

Page count

In the period from 1994 to 2003, there were 13,279 pages in total of 1,551 publications for an average of 8.6 pages per publication. Among these papers, 50 (3.2%) papers were consisted of one or two pages with CPP value of 0.70, which included 28 meeting abstracts without any citation. Forty-four (2.8%) papers were published at least 20 pages including 15 reviews with CPP value of 3.4. The highest value of CPP was 12.5 which were reviews with 40 pages. Five to nine pages were popular accounting for 59% and six-page papers (219, 14%) were dominant with CPP value of 3.2. Then it was followed by ten (113, 7.3%) with 3.8 CPP, four (97, 6.3%) with 2.2 CPP, and eleven (88, 5.7%) with 4.5 CPP. When page of a paper increased from one to eleven, the value of CPP also increased. It is clear that review paper had higher page count and CPP but meeting abstract had only one page without citation.

Publication output

Figure 2 shows the publication output from 1994 to 2003. A significant correlation was found between the yearly cumulative number of publications and the year. In 1994, 18 papers were published. After only one year, it increased to 157 and in 2003 the cumulative number of publications was 1,551. Meanwhile, the value of CPP also increased in two stages. From 1995 to 1999, the mean value of CPP was 2.9, while it increased to 3.5 in recent four years. The relationship between yearly cumulative number of publications and the year was linear with a high coefficient of determination (0.999). It suggested there is a constant publication rate in each year and about 150 papers per year for PCP research [HSIEH & AL., 2004].

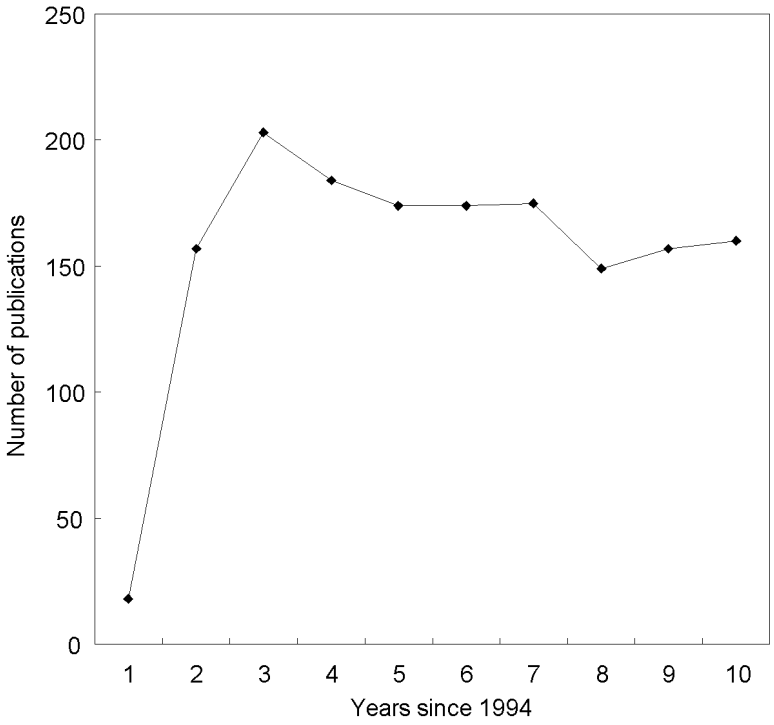

Figure 2. Annual publication output in pentachlorophenol research

Authorship

Average authors per document from 1994 to 2003, was 3.6 with CPP 3.1. Figure 3 shows the distribution of publications and citation per publication by number of authors. Among 1,551 papers, 74 (4.8%) papers were consisted of one author. Eight (0.5%) which were all come from single country had more than 10 authors. The most-frequent number of authors was 2 to 5 according for 84% and three-author papers were dominant. The value of CPP was varied with the number of authors. Seven-author papers had the highest CPP (5.5), followed by nine-author papers (4.8). The CPP mean value was 2.9 for less than four authors' papers, 4.3 for five to nine authors' and 1.3 for more than ten authors'.

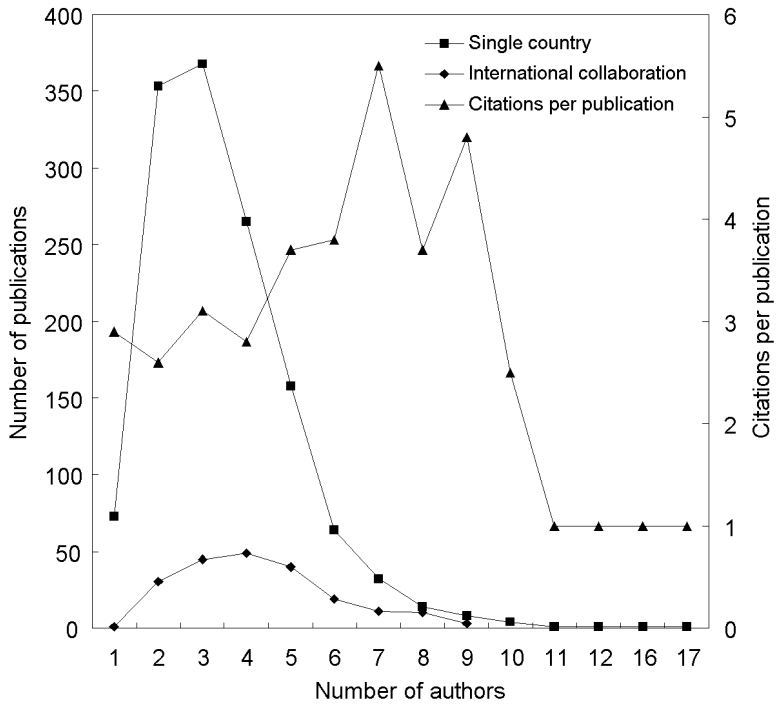

Figure 3. Distribution of publications and citations by number of authors between 1994 and 2003

Keywords plus analysis

Research trend is always concerned by researchers. Keyword analysis was performed to offer the information of research trend. Keywords plus in the Science Citation Index (SCI) database supplied additional search terms extracted from the titles of articles cited by authors in their bibliographies and footnotes [GARFIELD, 1990]. Table 1 shows distribution of keywords plus appearance more than 15 times. The most frequently used keywords for all periods were 'Pentachlorophenol' and 'PCP' as abbreviation became popular in recent year. Both degradation and biodegradation were emphasis of PCP research all along. From the result of analysis of article keywords, 31 keywords included degradation which appeared 595 times. Further study was considered to compare eight of those keywords accounting for 93% of 595 times.

Figure 4 shows articles included keywords 'degradation'; 'biodegradation' including microbial-degradation, anaerobic biodegradation, and anaerobic degradation; 'photodegradation' including photocatalytic degradation; and 'sonochemical degradation'. It is clear that the research on PCP degradation reached the peak in 1996 when McAllister reviewed PCP degraded by microorganism [MCALLISTER & AL., 1996].

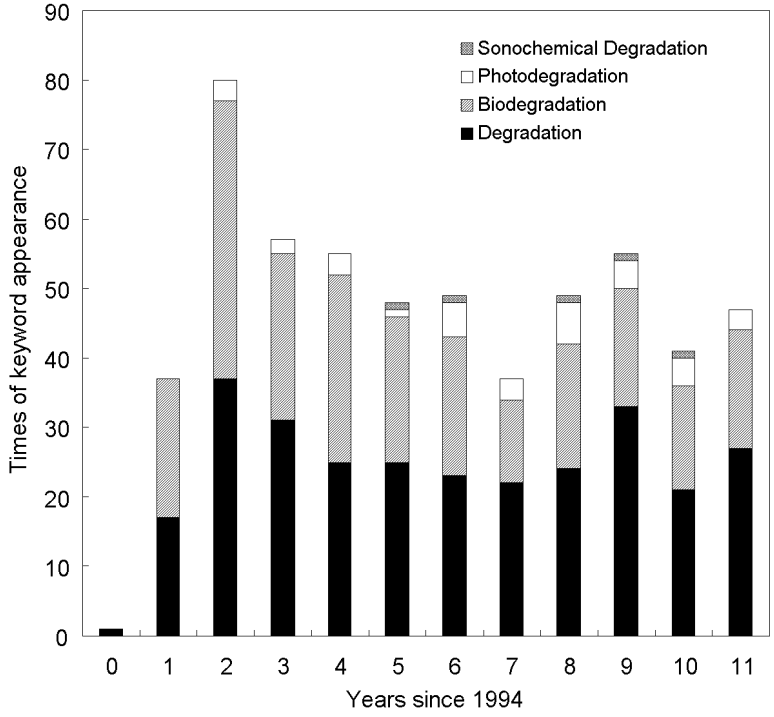

Figure 4. Times of keywords included 'degradation' appearance

After this, the biodegradation research focused on degradation pathway, intermediates and enzymes besides degradation microorganism. Because of its resistant degradation and toxicity, PCP's abiotic degradation processes such as photodegradation and sonochemical degradation had also been studied. Traditional researched on the PCP contaminant in various environmental medium such as 'water', 'soil', 'sediment', and 'toxicity' to biology was still in consideration. However, there were also some keywords that became more active in this research field. For example, 'adsorption' or 'sorption' that is a traditional method for removing persistent organic pollutants [MOLLAH & ROBINSON, 1996; ZHU & AL., 2000] ranked 44th and 27th in 1994–1996, while it ranked 30th and 19th in 1997–1999, and top10th and 13th in 2003–2005.

Therefore degradation and sorption were mainly PCP research fields. Moreover, 'in vitro' study was getting more concerned in recent year which ranked 13th in 2003–2005, while it had no appearance in 1994–1999. Toxicity and endocrine disruption effects of PCP were emphasis of in vitro research.

Table 1. Keywords plus citing rank and percentage of publication in different period

Keywords plus	1994–1996	1997–1999	2000–2002	2003–2005
Pentachlorophenol	1 (37)	1 (35)	1 (34)	1 (37)
Degradation	2 (17)	2 (17)	2 (16)	2 (19)
Water	4 (7.8)	4 (11)	3 (12)	3 (13)
Chlorophenols	7 (6.6)	5 (9.8)	6 (6.9)	4 (11)
Biodegradation	3 (15)	3 (12)	4 (9.6)	5 (9.8)
Soil	6 (7.2)	6 (8.2)	5 (7.8)	6 (7.1)
Oxidation	23 (2.7)	12 (4.7)	8 (5.3)	7 (6.2)
Toxicity	12 (4.2)	7 (6.3)	7 (6.5)	7 (6.2)
Polycyclic Aromatic-Hydrocarbons	23 (2.7)	30 (2.2)	46 (1.8)	9 (5.7)
Adsorption	44 (1.8)	30 (2.2)	20 (2.9)	10 (5.5)
Chlorinated Phenols	8 (6.3)	13 (4.5)	10 (3.8)	11 (5.3)
Phenols	13 (3.9)	14 (4.1)	8 (5.3)	12 (4.8)
Aqueous-Solution	167 (0.6)	92 (1.0)	53 (1.6)	13 (4.3)
In-Vitro	NA	NA	36 (2.0)	13 (4.3)
Sorption	27 (2.4)	19 (3.3)	33 (2.2)	13 (4.3)
Pesticides	44 (1.8)	23 (2.9)	28 (2.4)	16 (4.1)
Sediments	9 (4.8)	14 (4.1)	19 (3.1)	16 (4.1)
Exposure	44 (1.8)	19 (3.3)	15 (3.3)	18 (3.9)
Dechlorination	27 (2.4)	17 (3.9)	10 (3.8)	19 (3.7)
Kinetics	23 (2.7)	18 (3.7)	15 (3.3)	19 (3.7)
Metabolism	5 (7.5)	8 (6.1)	20 (2.9)	19 (3.7)

Publication patterns

In total, 1,551 papers were published in 431 journals. Journal distribution analysis showed 241 (56%) journals contained only 1 document, 61 (14 %) journals contained 2, 39 (9.0%) journals contained 3, 13 (3.0%) journals contained 4 documents. Table 2 listed core journals on PCP research with the number of papers, percentage of total documents, CPP, impact factor of journals, ISI category of journals, and journal rank in the category. *Chemosphere* published the most papers 108 (7.0%). Then it was followed by *Environmental Science and Technology* which ranked first in engineering and environmental category and *Water Research* which ranked first in Water Resources category. Moreover, *Environmental Health Perspectives* which ranked first in both environmental science and Public, Environmental and Occupational Health category ranked 11th with 19 published papers and had the highest CPP (9.6) and the highest IF (5.342) among the 17 journals listed in Table 2.

Table 2. Core journals with the number of papers, impact factor, CPP, ISI category of journals and its rank in the category

Journal	P (%)	CPP	IF	Subject category	Rank
Chemosphere	108 (7.0)	3.2	2.297	Environmental Sciences	21/140
Environmental Science & Technology	64 (4.1)	5.6	4.054	Engineering, Environmental Environmental Sciences	1/37 5/140
Water Research	49 (3.2)	3.6	3.019	Engineering, Environmental Environmental Sciences Water Resources	3/37 8/140 1/57
Environmental Toxicology and Chemistry	43 (2.8)	3.4	2.414	Environmental Sciences Toxicology	18/140 16/75
Applied Microbiology and Biotechnology	28 (1.8)	4.3	2.586	Biotechnology & Applied Microbiology	39/139
Applied and Environmental Microbiology	25 (1.6)	6.8	3.818	Biotechnology & Applied Microbiology Microbiology	21/139 19/86
Journal of Chromatography A	24 (1.5)	6.5	3.096	Biochemical Research Methods Chemistry, Analytical	13/53 7/70
Aquatic Toxicology	24 (1.5)	2.7	2.719	Marine & Freshwater Biology Toxicology	4/77 11/75
Archives of Environmental Contamination and Toxicology	24 (1.5)	3.8	1.408	Environmental Sciences Toxicology	53/140 51/75
Water Science and Technology	23 (1.5)	1.5	0.875	Engineering, Environmental Environmental Sciences Water Resources	19/37 96/140 29/57
Environmental Health Perspectives	19 (1.2)	9.6	5.342	Environmental Sciences Public, Environmental & Occupational Health	1/140 1/99
Journal of Molecular Structure	19 (1.2)	2.6	1.44	Chemistry, Physical	62/111
Bulletin of Environmental Contamination and Toxicology	18 (1.2)	1.2	0.626	Environmental Sciences; Toxicology	116/140 65/75
Biotechnology and Bioengineering	16 (1.0)	2.6	2.483	Biotechnology & Applied Microbiology	43/139
Soil Biology & Biochemistry	16 (1.0)	1.9	2.414	Agriculture, Soil Science	1/29
Biochemical and Biophysical Research Communications	15 (0.97)	3.1	3.000	Biochemistry & Molecular Biology; Biophysics	97/261 21/65
Journal of Hazardous Materials	15 (0.97)	3.3	1.544	Engineering, Environmental; Engineering, Civil; Environmental Sciences	5/37 2/80 45/140

P (%): Number of publications and percentage of total publication for a certain journal; CPP: Citations per publication; IF: Impact factor.

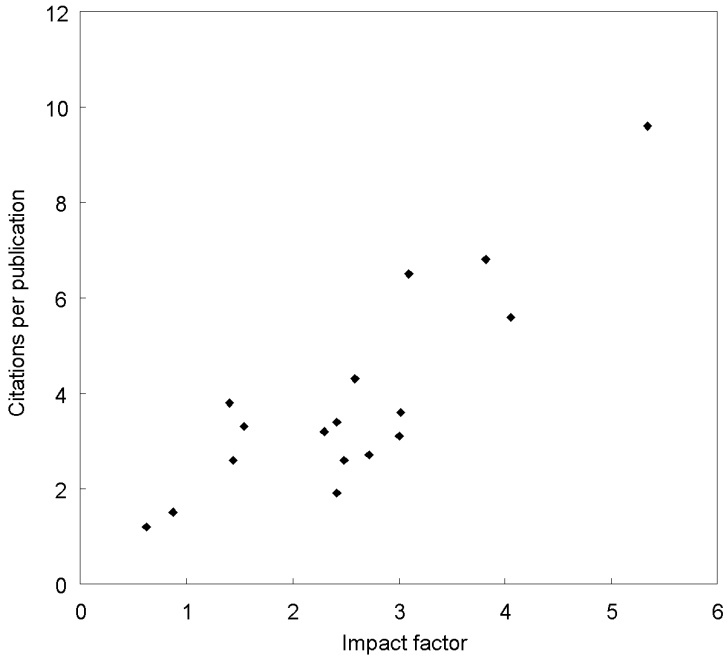

Figure 5. Relation between impact factor and citations per publication for core journals

However, *Chemosphere* which published the most number of papers has a CPP of 3.2, and an IF of 2.297, ranked 10th and 12th respectively out of core journals. Impact factor of a journal is defined by the JCR, and is a measure of the frequency with which the average paper in a journal has been cited in a particular year. For PCP papers published in core journals, the number of times being cited was associate with the impact factor of journals that publish these papers. Figure 5 shows there was a positive correlation between CPP and IF. It seems that CPP and IF both are useful to show the importance of journals. However, impact factor changes over year and presents the relevance of journals in a certain period. In addition, two journals worth noting were *Environmental Toxicology and Chemistry* and *Soil Biology and Biochemistry* which has the same value in IF (2.414), but CPP was 3.4 and 1.9 respectively. It means CPP maybe more adequate to evaluate journal's relative importance in a long period especially for a particular research. There were 166 (12%) papers without IF information on the ISI *web of Science*. Figure 6 showed the distribution of papers by reference to their IF and CPP. Among 1,385 papers, 1,059 (76.5%) had an IF of 0–3, while 927 (66.9%) had a CPP of 1–4.

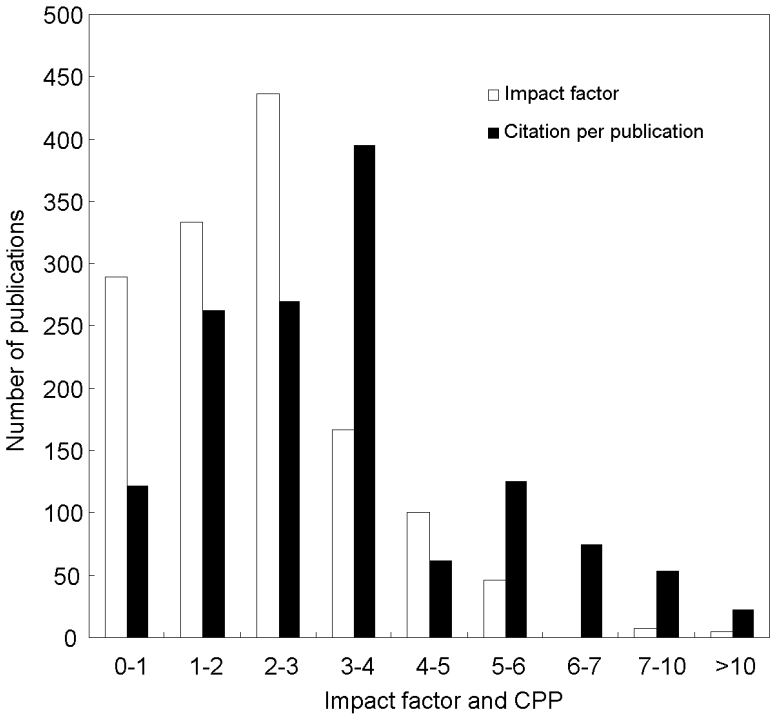

Figure 6. Distribution of publication by reference to impact factor and CPP

Citation analysis

There were 4,840 citations in the total of 1,551 documents for an average of 3.1 citations per document. Among pentachlorophenol research papers, the most frequently cited was 'Environmental xenobiotics may disrupt normal endocrine function by interfering with the binding of physiological ligands to steroid receptors and binding proteins'. This paper published by DANZO [1997], in the *Environmental Health Perspectives* was cited 138 times since it was published to 2005. The results of this paper showed that PCP could cause a statistically significant inhibition of specific binding of [^{3}H] 5α-DHT to the androgen receptor and reduced [^{3}H] 17β-estradiol binding to the estrogen receptor. Figure 7 shows the citations of the publications had a significant trend. Logistic curve fitting suggested the coefficient of determination was as high as 0.996 between number of publications and citations.

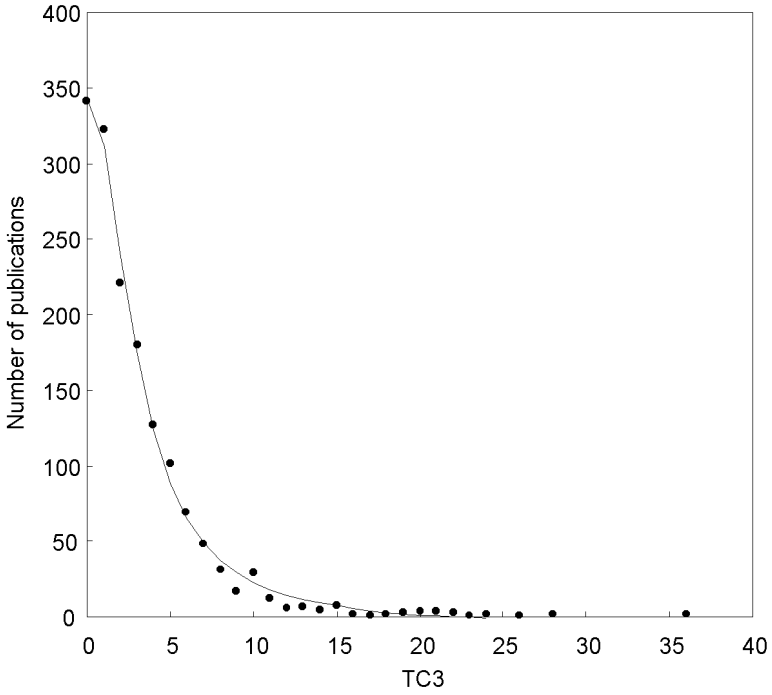

Figure 7. Relationship between number of publications and citations with simulated curve

Country of publication

Among the 1,551 papers, 209 (13%) publications were international collaboration covering 47 different countries, and 1,342 were independent publication covering 52 different countries. Five countries had no independent and 10 countries had no collaborative publications. There was only one paper without author address information. Table 3 listed countries/territories, which had total publications more than 2% of all papers. The USA, Canada, Germany, Japan, UK, and France are G7 country, published 64% independent papers. USA published the most number of international collaboration papers 90(43%), followed by Germany and Canada. Comparing with country/territory ranking in all fields (from 1996–2006 data), the total paper published by Finland, Taiwan and Poland was rather more, ranked 8th, 9th and 11th. That showed that, as countries severely contaminated by PCP, they have paid more attention to the PCP's research. Papers published by the top 5 countries listed in Table 3 had a higher

citation rate in both independent and dependent publications, which means these countries not only published mostly papers but also higher citation papers. Sweden concentration on PCP exposure and toxicity had the highest CPP_T (8.5) and CPP_S (9.5) in all countries/territories. For Taiwan and South Korea, the value of CPP_S (2.9) was higher than CPP_C (1.0), and the most frequency cooperating partner was USA. However, for 42 countries have both independent and dependent publications, mean value of CPP_C (3.5) was higher than CPP_S (3.1), which means international collaboration always produce higher impact and visibility publications in the research field.

Table 3. Publication productivity of country/territory, CPP, CPP rank and country/territory ranking in all fields

Country	TP (%)	CPP_T (Rank)	SP	CPP_S (Rank)	CP	CPP_C (Rank)	Rank
USA	480 (30.9)	3.2 (17)	390 (29.0)	3.1 (13)	90 (43.0)	3.7 (17)	1
Canada	186 (12.0)	3.6 (8)	148 (11.0)	3.3 (9)	38 (18.0)	4.4 (7)	7
Germany	162 (10.4)	3.5 (9)	122 (9.1)	3.3 (9)	40 (19.0)	4.1 (9)	4
Japan	102 (6.6)	3.3 (14)	83 (6.2)	3.1 (13)	19 (9.1)	3.8 (15)	3
UK	95 (6.1)	3.5 (9)	65 (4.8)	3.2 (12)	30 (14.0)	4.0 (10)	2
France	75 (4.8)	2.9 (19)	57 (4.2)	2.9 (19)	18 (8.6)	2.8 (24)	5
Spain	54 (3.5)	4.3 (5)	37 (2.8)	4.7 (3)	17 (8.1)	3.5 (18)	10
Finland	52 (3.4)	3.5 (9)	39 (2.9)	3.4 (8)	13 (6.2)	3.9 (14)	26
Taiwan	50 (3.2)	2.5 (27)	39 (2.9)	2.9 (19)	11 (5.3)	1.0 (35)	18
China	42 (2.7)	1.9 (37)	28 (2.1)	1.6 (32)	14 (6.7)	2.6 (27)	6
Poland	41 (2.6)	2.8 (23)	25 (1.9)	2.2 (24)	16 (7.7)	3.8 (15)	19
South Korea	40 (2.6)	1.8 (39)	23 (1.7)	2.0 (27)	17 (8.1)	1.5 (33)	14
Netherlands	38 (2.5)	3.5 (9)	26 (1.9)	4.0 (5)	12 (5.7)	2.5 (29)	12

TP: Total country publications; CPP_T: Citation per publication of total country publication; SP: Single country publications; CPP_S: Citation per publication of single country publication; CP: International collaboration publications; CPP_C: Citation per publication of international collaborated publication.

Conclusion

The study showed that the indicator of CPP provided an effective way to assess impact of a publication. A 4th year citation acme was found in the pentachlorophenol research. Five to nine pages were dominant. When page of a paper increased from one to eleven, the value of CPP also increased. The most-frequent number of authors was 2 to 5. For the core journals, there was a positive correlation between CPP and IF. The countries of publication denoted that most of these researches were done by USA, Canada, Germany, Japan, UK, and France. For countries both have independent and dependent publication, mean value of CPP_C was higher than CPP_S. The paper denoted that yearly publications sustain constantly in each year. There were a logistic relationship between number of publications and citations. Both degradation and biodegradation were emphasis of PCP research. Researchers made more attention to adsorption or sorption and 'in-vitro' study of PCP in recent years.

References

CHHABRA, R. S., MARONPOT, R. M., BUCHER, J. R., HASEMAN, J. K., TOFT, J. D., HEJTMANCIK, M. R. (1999), Toxicology and carcinogenesis studies of pentachlorophenol in rats. *Toxicological Sciences*, 48 (1) : 14–20.

DANZO, B. J. (1997), Environmental xenobiotics may disrupt normal endocrine function by interfering with the binding of physiological ligands to steroid receptors and binding proteins. *Environmental Health Perspectives*, 105 (3) : 294–301.

DIMICH, W. H., HERTZMAN, C., TESCHKE, K., HERSHLER, R., MARION, S.A., OSTRY, A., KELLY, S. (1996), Reproductive effects of paternal exposure to chlorophenate wood preservatives in the sawmill industry. *Scandinavian Journal of Work Environment and Health*, 22 : 267–273.

ENGWALL, M. A., PIGNATELLO, J. J., GRASSO, D. (1999), Degradation and detoxification of the wood preservatives creosote and pentachlorophenol in water by the photo-Fenton reaction. *Water Research*, 33 (5) : 1151–1158.

GARFIELD, E. (1990), KeyWords Plus: ISI's breakthrough retrieval method. Part 1. Expanding your searching power on Current Contents on Diskette. *Current Contents*, 32 : 5–9.

HSIEH, W. H., CHIU, W. T., LEE, Y. S., HO, Y. S. (2004), Bibliometric analysis of patent ductus arteriosus treatments. *Scientometrics*, 60 (2) : 205–215.

KIEFER, M. C., HENGRAPROM, S., KNUTESON, S. (1998), *Environmental Organic Chemistry*, Springer, Berlin.

MCALLISTER, K. A., LEE, H., TREVORS, J. T. (1996), Microbial degradation of pentachlorophenol. *Biodegradation*, 7 (1) : 1–40.

MOLLAH, A. H., ROBINSON, C. W. (1996), Pentachlorophenol adsorption and desorption characteristics of granular activated carbon. I. Isotherms. *Water Research*, 30 (12) : 2901–2906.

SANDAU, C. D., AYOTTE, P., DEWAILLY, E., DUFFE, J., NORSTROM, R. J. (2000), Analysis of hydroxylated metabolites of PCBs (OH-PCBs) and other chlorinated phenolic compounds in whole blood from Canadian Inuit. *Environmental Health Perspective*, 108 : 611–616.

SJODIN, A., HAGMAR, L., KLASSON-WEHLER, E., BJORK, J., BERGMAN, A. (2000), Influence of the consumption of fatty Baltic Sea fish on plasma levels of halogenated environmental contaminants in Latvian and Swedish men. *Environmental Health Perspective*, 108 : 1035–1041.

US ENVIRONMENTAL PROTECTION AGENCY (1980), Health and Environmental Effects Profile No. 135, Washington, DC.

ZHU, L. Z., CHEN, B. L., SHEN, X. Y. (2000), Sorption of phenol, p-nitrophenol, and aniline to dual-cation organobentonites from water. *Environmental Science & Technology*, 34 (3) : 468–475.