

# **Bibliography of Work on the Heterogeneous Photocatalytic Removal of Hazardous Compounds from Water and Air**

**Update Number 4 to October 2001**

**Daniel M. Blake**



**NREL**

**National Renewable Energy Laboratory**

1617 Cole Boulevard  
Golden, Colorado 80401-3393

NREL is a U.S. Department of Energy Laboratory  
Operated by Midwest Research Institute • Battelle • Bechtel

Contract No. DE-AC36-99-GO10337

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## Summary

This report is the fifth in a series of bibliographies of work on the photocatalytic oxidation of organic or inorganic compounds in air or water and on the photocatalytic reduction of inorganic compounds in water that were published in May 1994, October 1995, January 1997, and January 1999. The previous reports included 663, 574, 518, and 1517 citations, respectively. This update contains information extracted from 1149 new references to papers, books, and reports from searches done between October 1996 and April 2001. There are an additional 325 references to literature from a search that covered the period April to October 2001. These are not cited in the body of the report. There are also 1555 new patents referenced to October 2001. The new citations include some references from prior years that were not included in the previous reports. The general focus of the work is removing hazardous chemical or biological contaminants from air, water, and surfaces. This report also references work on properties of semiconductor photocatalysts and the application of photocatalytic chemistry in organic synthesis. The organization is the same as in the previous reports in this series. Patents are again included as a separate list because of the large number that are being published. The first part of the report gives citations for work done in a few broad categories that are generic to the process. Three tables provide references to work on specific substances. The first covers organic compounds that are included in various lists of hazardous substances identified by the U.S. Environmental Protection Agency (EPA). The second lists compounds not included in that table, but that have been treated in a photocatalytic process. The third covers inorganic compounds that have been treated by a photocatalytic process.



## Table of Contents

1.0 Introduction .....	1
2.0 Generic Information .....	3
2.1 Reviews and Articles .....	3
2.2 Photocatalysts .....	3
2.2.1 Modified Titanium Dioxide .....	4
2.2.2 Hydrophobic/Hydrophilic Surface Treatment .....	4
2.2.3 Dye Sensitized Titanium Dioxide .....	4
2.2.4 Metal Ion Doping of Titanium Dioxide or Mixed Oxides .....	5
2.2.5 Metallized Titanium Dioxide .....	5
2.2.6 Other Semiconductors .....	5
2.2.7 Immobilized Photocatalysts .....	5
2.3 Hydrogen Peroxide and Other Oxidants .....	6
2.4 Engineering Issues .....	6
2.4.1 Reactor and System Design .....	6
2.4.2 Systems Analysis .....	7
2.5 Miscellaneous Topics .....	7
2.6 Patents .....	8
2.7. Companies Active in the Field .....	8
3.0 Compounds Studied .....	9
4.0 Conclusions .....	39
5.0 Bibliography .....	40
5.1 Published Material .....	40
5.1.1 Work cited in this report .....	40
5.1.2 Additional references from a search conducted in October 2001 .....	118
5.2 Patents .....	140
5.3 Address for Sending Corrections or Additions to the Bibliography .....	253
6.0 Distribution List .....	254



## 1.0 Introduction

This update in combination with the previous reports<sup>1,2,3,4</sup> provides a comprehensive bibliography of the published work on photocatalytic chemistry and processes available in the open literature. It will be of most use to scientists and engineers interested in using heterogeneous photocatalytic oxidation or reduction processes in environmental remediation, process emission control, indoor air quality, or other applications in which oxidation or reduction chemistry on illuminated semiconductor surfaces can occur. A few citations are included for work on photoelectrochemical systems for water splitting or electricity production but these are major areas of research in their own right and are not included in the literature survey. Because of the large number of documents, no attempt has been made to critically assess the information in the cited literature. The combined reports include more than 6200 citations to work published between 1970 and the middle of 2001. The literature cited includes U.S. and foreign patents. Information was compiled by manually scanning the literature and by searching commercial databases. This update includes some citations to work done before 1999 that were not included in the previous reports. Some citations have doubtless been missed, and topics covered in some papers may not have been identified and covered in every appropriate category. The author is grateful to the many people who sent references and reprints of their work. Coverage is limited to heterogeneous processes, except in a few cases where review material for homogeneous processes is relevant to heterogeneous photocatalytic chemistry. The author invites readers to send references to relevant work that has been missed to the mailing or e-mail address included in Section 5.3.

The number of new publications, including patents, continues to grow each year, as shown in the plot in Figure 1. The growth in patents is primarily due to the high level of commercial interest in applications being developed in Japan. The number of papers, reports, and conference proceedings has leveled off at about 400 per year. The low number for 2001 reflects the fact that the search for the current year includes only the material available during the first half of the year.

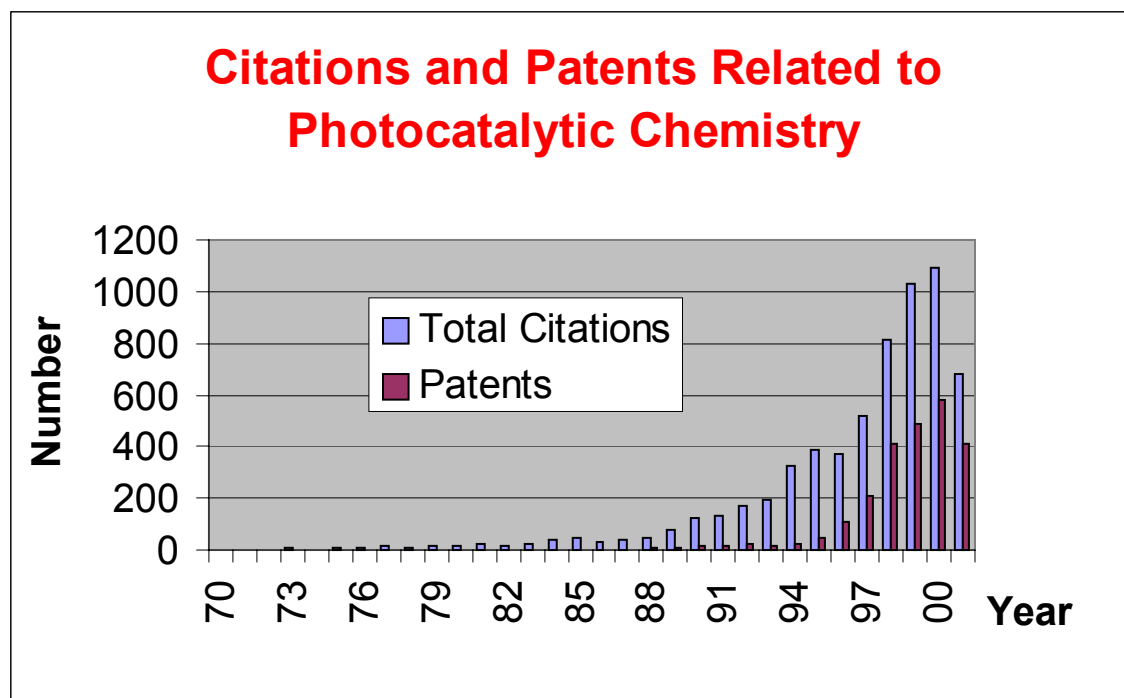
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<sup>1</sup>Blake, Daniel M. (1994). *Bibliography of Work on the Photocatalytic Removal of Hazardous Compounds from Water and Air*. NREL/TP-430-6084. Golden, CO: National Renewable Energy Laboratory. 75 pp. [DE94006906]. Available from the National Technical Information Service, Springfield, VA 22161.

<sup>2</sup>Blake, Daniel M. (1995). *Bibliography of Work on the Photocatalytic Removal of Hazardous Compounds from Water and Air. Update Number 1, to June 1995*. NREL/TP-473-20300. Golden, CO: National Renewable Energy Laboratory. 102 pp. Available from the National Technical Information Service, Springfield, VA 22161.

<sup>3</sup>Blake, Daniel M. (1997). *Bibliography of Work on the Photocatalytic Removal of Hazardous Compounds from Water and Air. Update Number 2, to October 1996*. NREL/TP-430-22197. Golden, CO: National Renewable Energy Laboratory. 88 pp. Available from the National Technical Information Service, Springfield, VA 22161.

<sup>4</sup>Blake, Daniel M. (1999). *Bibliography of Work on the Photocatalytic Removal of Hazardous Compounds from Water and Air. Update Number 3, to January 1999*. NREL/TP-570-26797. Golden, CO: National Renewable Energy Laboratory. pp 163. Available from the National Technical Information Service, Springfield, VA 22161.



**Figure 1. Citations and patents related to photocatalytic chemistry.**

The photocatalytic oxidation of organic compounds in water has received the most attention, but there is a rapidly increasing amount of work on the oxidation of volatile organic or inorganic compounds in the gas phase. Photocatalytic reduction of organic compounds and metal-containing ions is also well established. Studies of cell killing and disinfection by illuminated titanium dioxide ( $\text{TiO}_2$ ) have also been increasing in number. More than 1000 substances have been tested to date.

References to test work on new compounds is included in the tables in Section 3. The most-studied compounds are phenol derivatives, dye compounds as a class, pesticides and herbicides as a class, oxides of nitrogen, and chlorinated solvents such as tri- and per-chloroethylene and chloroform. Researchers have found that, in the presence of  $\text{TiO}_2$ , a wide range of surfacants are mineralized and a variety of bacteria, viruses, cancer cells, and other cell types are killed by irradiation with near ultraviolet light. A wide range of high molecular weight compounds representative of surface soiling agents have been studied as part of the work on self-cleaning surfaces. The breadth of work attests to the very wide range of applications that are being considered for the technology. The self-cleaning and wetting properties of irradiated titanium dioxide surfaces are now the subjects of a high level of interest because of the potential for commercial applications.

The section on companies active in the field has not been updated for this report because little new information was available to the author. The high level of R&D activity directed toward commercial development, particularly by Japanese companies, is indicated by the continued patent activity (see the patent list in Section 5.2). The assignees can give an indication of the companies involved in the field.

The following sections cover reviews written on various aspects of the technology, work in developing and testing photocatalysts and oxidants, engineering issues, other topics, and patents. These sections include information that can apply to a range of applications. They are followed by tables listing references to work performed on specific substances. References to work on systems in which the compound to be treated is carried in the gas phase or on a surface exposed to air are indicated by the prefix “g” in the citation number.



## 2.0 Generic Information

This section references work that spans the field of photocatalytic processes.

### 2.1 Reviews and Articles

Reviews have been written covering many aspects of photocatalytic chemistry and technology. This section also includes reviews written before 1999 that were not cited in the previous reports. Reviews covering the broad topics can be found in the following:

General coverage – 57, 250, 310, 311, 320, 350, 363, 472, 492, 517, 527, 561, 624, 685, 738, 772, 779, 787, 816, 856, 893, 894, 924, 951, 952, 955, 986, 990, 1001, 1084, 1105, 1121; semiconductors and supports – 17, 18, 24, 255, 256, 261, 277, 350, 365, 448, 472, 517, 542, 584, 598, 671, 674, 764, 767, 772, 826, 879, 880, 893, 952, 1003, 1005, 1008, 1016, 1017, 1025, 1040, 1041, 1059, 1069, 1110; photocatalytic reactors – 429, 1025; methodology for comparing reaction systems – 54, 96, 161, 162, 776; mechanisms/activity – 776; femtosecond diffuse reflectance spectroscopy – 255, 256; nanocrystalline semiconductors – 147, 340, 404, 406, 495, 584; photoelectrochemical systems - no new reports; solar – 61, 150; companies active in the field – 806; adsorption – no new reports; disinfection, cell killing, and toxicology – 6, 58, 238, 241, 242, 243, 295, 297, 602, 679, 749, 836, 880, 955, 961, 1004, 1083; water treatment – 6, out of, 624, 986; indoor air quality – 236, 238, 241, 242, 243, 295, 655, 679, 750, 779, 855, 880; environmental applications – 17, 20, 22, 23, 25, 252, 259, 277, 320, 337, 345, 356g, 524, 358, 538, 553, 558, 620g, 621g, 622g, 623g, 624, 738, 857, 858, 862g, 863g, 864g, 865g, 892, 955, 1008, 1016, 1041, 1043, 1063; self-cleaning surfaces – 55, 237, 239, 240, 241, 242, 295, 296, 297, 408, 558, 655, 679, 855, 858, 892, 955, 956, 957, 959, 960; energy storage – no new reports; preparation and application of semiconductor thin films and coatings – 237, 455, 958, 961, 1040, 1041, 1059, 1110; iron doped titanium dioxide as photocatalysts – no new reports; organic synthesis – 20, 399, 747, 816; carbon dioxide reduction – 399, 1029; water splitting – 769; intercalation compounds – no new reports; oxidation of chlorophenols – no new reports; comparison of advanced oxidation processes – 130; issues and questions in application of photocatalysis – no new reports; reactors – 96; problems of immobilization of catalyst – no new reports; fate of organic nitrogen – 2; activation of oxygen – no new reports; surfactant removal – no new reports; charge injection into semiconductor particles – 1029; activating titanium dioxide with visible light – 17, 18, 19, 20, 21, 22, 23, 24, 25, 320, 1040; specialty grades of titanium dioxide – 29, 251, 256, 328, 1039; comparison of advanced pollution control methods – 130; mechanisms of polymer degradation – 552; photography and imaging – no new reports; analytical chemistry applications – 665; pesticide oxidation – 130; applications and markets – 16, 228, 238, 241, 252, 295, 296, 297, 299, 363, 431, 438, 472, 492, 584, 620g, 685, 746, 748, 787, 806, 855g, 856, 857, 858, 951, 952, 990, 1001, 1017, 1039, 1069.

### 2.2 Photocatalysts

The nature of the photocatalyst determines the rate and efficiency of the process. The anatase form of titanium dioxide has the desirable properties of being chemically stable, readily available, and active as a catalyst for oxidation processes. The 3.2 eV band gap matches the output of a wide variety of readily available lamps but is not ideal for solar applications. Rutile has a smaller band gap, 3.0 eV, but only a few reports observe photocatalytic activity for this form. The photo efficiency for reaction of target molecules is generally rather low, particularly for the aqueous phase processes. A major body of work has been directed toward modifying titanium dioxide and testing other semiconductors to identify ways to increase process efficiency and to improve the overlap of the absorption spectrum of the photocatalyst with the solar spectrum. This work is broken down into a few broad categories and covered in the references cited.





### **2.2.1 Modified Titanium Dioxide**

Titanium dioxide and modified forms, including commercially available forms, heat-treated materials, and materials prepared by a range of techniques:

sol-gel – 1, 7, 31, 56, 80, 84, 85, 88, 109, 145, 146, 148, 162, 179, 190, 214, 221, 234, 247, 299, 300, 305, 316, 330, 332, 333, 368, 378, 382, 383, 384, 389, 420g, 421g, 435, 436, 443, 481, 511, 562, 636, 637, 696, 711, 713, 726, 743, 744, 755, 785, 841, 856, 878, 923, 925, 946, 1013, 1037, 1057, 1062, 1064, 1070, 1109; controlled hydrolysis of  $\text{TiCl}_4$  or  $\text{Ti(OR)}_4$  – 91, 92, 98, 284, 470, 997, 1094, 1114; hydrothermal treatment – 76, 435, 436, 437, 687, 1014, 1056; heat treatment – 98, 119, 169, 170, 190, 268, 294, 331, 372, 382, 397, 437, 470, 481, 497, 498, 646, 692, 701, 725, 743, 780, 929, 1078, 1119, 1120; microwave – 39, 910; colloidal, quantized, or nano-crystalline – 88, 126, 153, 157, 163, 165, 166, 274, 275, 319, 388g, 389g, 405, 410, 490, 491, 500, 512, 540g, 675, 762, 910, 965, 1085, 1086, 1112, 1113, 1124; nanotubules – 1, 404, 1116; xerogel/aerogel – 167, 168, 411, 786, 894; mesoporous – 152, 153, 154, 155, 157, 818, 819; interfacial gelling – 392; superacid – 234; fibers – 433, 927; electrochemical deposition – 565; flame synthesis – no new reports; titanium dioxide from different vendors – 29, 41, 51, 78, 125, 143, 161, 162, 178, 256, 282, 306, 370g, 374, 435, 436, 476g, 555g, 556g, 647, 739, 743, 934; spray pyrolysis – 98, 348g, 793, 794, 795, 796, 797, 798, 799; chemical vapor deposition – 77, 180, 283, 471, 477, 500, 609; plasma enhanced chemical vapor deposition – 38, 90, 93, 669, 670, 671, 683, 826; sputtered – 24, 193, 393, 577, 657, 732, 733, 789, 790, 842, 929, 935; epitaxial growth – 566; anodized titanium metal – 85, 86, 366, 369, 488; pyrolytic – 721; electrocomposite deposition – no new reports; impregnation – 519, 637; co-precipitation – no new reports; microemulsion – no new reports; ionized cluster beam – 1007, 1010; microroughened – 257; laser treatment – 475; laser micromachining – 257; reduction – 866; dip or spin coating – 80, 89, 309, 416, 634, 639, 640, 641, 642, 644, 878, 1062, 1065, 1066, 1068, 1071, 1072, 1703, 1074, 1075, 1076, 1077; thermal spraying – 284, 322; particle size effect – 224, 993, 1085, 1122, 1124; screen printing – no new reports; rutile – 47, 72g, 235, 256, 305, 376, 386g, 430, 501, 519, 550, 670, 827, 828, 901, 902, 1095, 1112, 1113, 1114, 1135, 1140; pillared and layered titanates – 1030, 1031; chelating groups – 541; cysteine, alanine, arginine, thiolactic acid – 575; surface modification – 541, 656, 657, 682, 1061; adsorbed surfactant – 1088; ion bombardment – 56, 827; ion implantation – 17, 18, 29, 20, 23, 24, 25, 26, 40, 300, 867, 868, 1011, 1012; X-ray treatment – 352; fluoride effect – 39; sulfonated surface – 822, 823, 1061; macropores formed using latex spheres as templates – no new reports; reducing photocatalytic activity – 351, 1015; effect of storage on activity – 417; effect of pretreatment on activity – 421g; combinatorial methods – 566.

### **2.2.2 Hydrophobic/Hydrophilic Surface Treatment**

Several approaches have been taken to change the surface of titanium dioxide to modify the hydrophobicity:

Silica gel – 401, 425; amphiphilic microfine titanium dioxide – 237; superhydrophilic or hydrophobic  $\text{TiO}_2$  – 55, 239, 240, 243, 281, 297, 298, 299, 301, 402, 513, 532, 533, 599, 601, 627, 628, 772, 851, 859, 860, 893, 954, 955, 956, 957, 959, 960, 1076; sunscreens – 463, 665; tethered organic compounds – no new reports; Langmuir-Blodgett films – no new reports.

### **2.2.3 Dye Sensitized Titanium Dioxide**

Sensitizers have been used in conjunction with titanium dioxide to improve the response to visible light:

ruthenium complexes – 101, 131, 900, 1060; vanadium(+5) complexes – no new reports; cobalt(+2) complexes – 1098; nickel(+2) complexes – 1098; copper(+2) complexes – no new reports; cobalt(+3) complexes – no new reports; iron(+2 or +3) – no new reports; palladium(II) chloride – 1098; rhodium(III) chloride – 1098; platinum(IV) chloride – 1097, 1098; iridium(IV) chloride – 1098; gold(III) chloride – 1098; metal phthalocyanine – no new reports; porphyrins – 221, 605; and organic dyes – 216, 237, 781, 976.

## 2.2.4 Metal Ion Doping of Titanium Dioxide or Mixed Oxides

Other metal ions have been introduced into the titanium dioxide lattice to modify the properties. They are covered in the following:

Li – 278, 378, 570; Mg – no new reports; Al – 49, 570, 681; Si – 167, 168, 1080; K – 279; Ca – 7, 279; V – 20, 21, 23, 26, 570, 651, 867, 1012; Cr – 21, 23, 108, 479, 867, 939, 966, 968, 970, 1012; Mn – 646; Fe – 23, 41, 108, 109, 170, 262, 379, 636, 637, 692, 696, 711, 715, 755, 926, 939, 940, 1032, 1080, 1124, 1130, 1139; Co – 371, 372, 939; Ni – 651, 939; Zn – 570, 939, 681; Ge – 248; Sr – 7; Zr – 85; Nb – 378, 392, 1124; Mo – 377, 967, 968, 1054; Ru – 646, 673, 998, 999; Rh – 23; Cd – 939; Sn – 93, 501; Sb – 480; Ba – 7; rare earth metals – 498, 568, 715, 808, 923, 925, 937, 1081, 1082, 1089, 1090, 1091; W – 76, 482, 483, 570, 600; Pb – 1068, 1127; Bi – 570.

## 2.2.5 Metallized Titanium Dioxide

Noble metals have been deposited on the titanium dioxide surface to enhance catalytic activity:

Ni – no new reports; Cu – 402, 812; Rh – 647, 717; Ru – 647, 1053; Pd – 113, 171, 316, 317, 393, 647, 998, 999, 1053, 1143; Pt – 29, 80, 75, 101, 110, 111, 112, 113, 178, 195, 196, 288g, 342, 426, 646, 647, 663g, 717, 789, 790, 901, 902, 919g, 920g, 984, 1032, 1138, 1140, 1143, 1148g; Ag – 145, 186, 347, 498, 646, 847, 848, 849; Au – 163, 186, 536, 537. Addition of metal powders (Cu, Ag, Zn, Ni, or Co) – 367g.

## 2.2.6 Other Semiconductors

A wide range of semiconductors and other materials has been tested for photocatalytic activity. They are generally less active than titanium dioxide. Relevant work is cited in the following:

MgO – no new reports; Al<sub>2</sub>O<sub>3</sub> – no new reports; SiC – no new reports; CaTiO<sub>3</sub> – 704; V<sub>2</sub>O<sub>5</sub> – 877g; Mn<sub>2</sub>O<sub>3</sub> – no new reports; Fe<sub>2</sub>O<sub>3</sub> – 47, 187, 386g; FeOOH – 47, 187; FeTiO<sub>3</sub> – no new reports; Co<sub>3</sub>O<sub>4</sub> – no new reports; ZnO – 42, 479, 187, 165, 249, 273, 550, 551, 645, 697, 1006; Zn- or CdS – 386g, 400, 410, 465, 548, 965; Pt/CdS – no new reports; CdSe – 127; ZnTe – no new reports; SrTiO<sub>3</sub> – 601; ZrO<sub>2</sub> – 66, 202, 891g, 1004; ZrTiO<sub>4</sub> – 635; MoO<sub>3</sub> – 121; MoS<sub>2</sub> – 890, 965; RuO<sub>2</sub> – 249; SnO<sub>2</sub> – 89, 491, 156, 965; Sb<sub>2</sub>O<sub>4</sub> – no new reports; TiO<sub>2</sub>/SnO<sub>2</sub> bi-layer - 302; BaTiO<sub>4</sub>O<sub>9</sub> – 538; CeO<sub>2</sub> – no new reports; WO<sub>3</sub> – 121, 386g, 548, 600, 673, 852, 935; Nb<sub>2</sub>O<sub>5</sub> – no new reports; RuS<sub>2</sub> – no new reports; Cs<sub>3</sub>PW<sub>12</sub>O<sub>40</sub> – 230; Na<sub>4</sub>W<sub>10</sub>O<sub>32</sub> – 886, 887, 888; PbS – 305; PbSe – 127; TiO<sub>2</sub>-MoO<sub>3</sub> core-shell materials - 200; hollandite – 608; layered perovskites – 271; fly ash - no new reports; furnace slag or core sands – no new reports; zeolite Y – 756, 757; polyaniline – no new reports; poly(p-phenylene) – no new reports; polythiocyanogen – no new reports; clays, mica, atmospheric aerosols, desert sand, volcanic ash, sea salt, chalk, or soot – no new reports.

## 2.2.7 Immobilized Photocatalysts

Most experimental work on aqueous systems has been performed using the photocatalyst in the form of fine particles suspended in the liquid phase. In a waste treatment application it would be simpler if the catalyst were immobilized in the photo reactor so the material would not have to be separated from the treated fluid in a subsequent process step. Most work for treating gases has been done with immobilized catalysts. Titanium dioxide has been affixed to a variety of surfaces:

glass (including fibers, soda lime, Pyrex, quartz, Vicor, and microspheres) – 75, 77, 94, 106, 116, 117, 118, 119, 145, 146, 193, 212, 214, 221, 229, 309, 318, 383, 454, 521, 578, 579, 580, 581, 584, 586, 588g, 598, 609, 620, 634, 639, 640, 641, 642, 643, 649, 662, 677, 698g, 699, 711, 712, 721, 722, 725, 734, 735, 736, 742, 783, 790, 802g, 804, 805, 810, 818, 830, 833, 834, 841, 842, 845,



865g, 868g, 881, 923, 924, 925, 929, 935, 938, 973, 979, 1007, 1010, 1011, 1043, 1044, 1045, 1047g, 1054g, 1055g, 1062, 1064, 1065, 1066, 1068, 1071, 1072, 1073, 1074, 1075, 1076, 1077, 1092, 1095, 1096, 1119, 1120, 1139, 1130, 1136; silica gel – 180, 247, 253, 288g, 355, 388g, 389g, 428, 511, 520, 535, 536, 537, 597, 663, 877, 946, 997, 1003, 1022, 1023, 1024, 1133, 1134; aerogels – 1049g; glass/ITO – 193, 194, 532, 712, 713, 1037; glass/SnO – 845, 853; metal – 84, 85, 86, 142, 165, 309, 346, 347, 357, 366, 367, 457, 478, 488, 509, 510, 558, 617g, 619, 668, 763, 865g, 1142; silicon – 193, 712, 979, 1062, 1092, 1143; clays – 179, 687, 861, 953, 1051, 1052, 1057; crysotile fibers – no new reports; organic polymer – 27, 206, 207, 208, 253, 258, 319, 359, 423, 434g, 457, 576, 583, 596, 598, 650, 789, 790, 864g, 865g, 883g, 915, 962g; thin films – 99, 152, 205, 283, 420g, 421g, 588g, 589g, 590g, 975; internal light guide – 578, 579, 580, 581, 582; zeolite – 18, 20, 22, 26, 31, 46, 153, 155, 245, 353, 397, 521, 905, 1009, 1106, 1141; concrete – 395, 598, 864g, 869g; pillared niobates – 1030, 1031; sepiolite – 245; alumina – 566; aluminite – 565; hydroxyapatite – 864; carbon – 148, 185, 292, 293, 308, 520, 521, 559, 560, 1007, 1010, 1051, 1052, 1149; membranes – 332, 333, 765, 871; paper – 432, 632, 679, 1047g; textiles – 408g, 434g, 598, 679, 804; Amborsorb – no new reports; PHOTOPERMTM – no new reports; magnetite – 53, 782; metal oxides and ceramics – 100, 107, 181, 182, 183, 184, 193, 245, 246, 253, 289, 354, 392, 449, 477, 514, 519, 542, 550, 551, 657, 716, 825, 854, 865g, 892, 1052, 1126, 1127, 1128, 1137; vesicles and micelles – no new reports; sand – 331, 702, 703; slag – no new reports; firebrick – 381, 521; pellets – 181, 182, 183, 184, 465; or unspecified – 356.

## 2.3 Hydrogen Peroxide and Other Oxidants

Oxygen is most common oxidant for photocatalytic reactions, but other oxidants have been found to improve reaction rates with a variety of organic substrates under some conditions. This work is covered in the following:

hydrogen peroxide – 34, 43, 79, 146, 156, 349, 462, 518, 638, 740, 1027, 1038; superoxide – 362; singlet oxygen – 216, 729, 1006; peroxydisulfate – 209, 543, 544, 545, 546, 547; chlorite, chlorate, bromate, or periodate, no new reports; nitrous oxide – no new reports; ozone – 164, 303, 427, 440, 441, 453, 654, 697, 698g, 754, 788g, 830, 871.

## 2.4 Engineering Issues

In recent years, the success of laboratory work has led to interest in applying the technology to environmental remediation and process waste stream treatment. Work in the literature addresses issues related to the scale-up of the process and resolution of engineering problems. Progress has been significant and some companies now provide turnkey systems for treating contaminated water and air. The largest market is for room air cleaners that are produced by companies in Japan exclusively for the Japanese market.

### 2.4.1 Reactor and System Design

Numerous papers have addressed topics relevant to designing reactors for photocatalytic processes:

photochemical reactors – 429; rotating disk or agitator reactor – 181, 182, 183, 184, 458, 460, 1042; pulsed baffled tube photoreactor – 206, 207, 208; non-concentrating reactor – 41, 173, 174, 177, 178, 217, 218, 229, 267, 553; parabolic trough – 94, 223; compound parabolic concentrator – 5, 59, 60, 94, 223, 267, 387, 587, 725, 737, 906, 907, 908, 909; kinetic modeling – 3, 10, 15, 36, 54, 68, 69, 70, 96, 110, 112, 144, 161, 162, 172, 173, 174, 202, 203, 222, 224, 267, 289g, 554, 572, 573, 585, 586, 591, 595, 684, 700, 710, 724, 752, 913, 918g, 1146g, 1147g; fluidized bed – 381, 474, 499g, 563g, 702, 703, 914g, 918g; packed bed – 215, 918g, 1019g; rotating drum reactor – 396, 899; filtration/catalyst separation – 107, 391, 489, 782, 814, 815, 843, 844, 985; controlled periodic



illumination – 73, 74g, 465, 918g; light scattering model – 1123; flat plate reactor – 70, 173, 174, 177, 178, 387, 914g, 962g; intermittent flow reactor – 158; ceramic monolith – 289g, 327, 753g, 854g; annular packed bed reactor – 739; annular thin film reactor – 162, 718, 719, 751g, 753g; falling film – 771; mass transfer limitations – 105, 172, 444, 445, 450; photocatalytic membrane reactor – 213, 606; fiber optic cable reactor – 133, 270g, 578, 579; cocurrent downflow bubble column contactor – 468; two phase, swirl flow monolith reactor - 104; ring roughened annular reactor – no new reports; laminar falling film slurry reactor – no new reports; shell and tube reactor - 459; water bell reactor – no new reports; air lift loop reactor – no new reports; Photo-CREC-Air reactor – 344, 778, 778; combined photocatalytic and biological system – 709; pilot tests – 61, 426, 571, 617, 962g, 1058g, 1118; materials for solar reactors – 61, 962g; solar resource assessment – 61; or treatment system design – 59, 60, 61, 224, 289g, 489, 571, 738, 854.

## 2.4.2 Systems Analysis

As the technology for photocatalytically treating contaminated air and water has progressed, some work on economic evaluation has appeared in the literature. New work is limited.

photon costs from lamps and sunlight –no new reports; marketing study –no new reports; solar processes – 5, 59, 60, 209, 387, 587, 737, 907; comparison of activated carbon with photocatalytic removal of air contaminants – no new reports.

## 2.5 Miscellaneous Topics

This category includes papers of interest that do not fall into the preceding headings:

actinometry – 54, 360, 184, 361, 913; adsorption – 71g, 197,198, 202, 203, 263, 461, 509, 554, 610, 727, 728, 837, 838, 839, 840, 861g, 996, 1035, 1088, 1094, 1102, 1144; combined photocatalytic and biological treatment – 43, 44, 47, 177, 178, 888, 1045, 1046; combined photocatalytic and ultrafiltration treatment –317; combined wet air oxidation and photocatalytic treatment – 192; effect of applied voltage bias on photocatalytic reactions – 79, 84, 85, 86, 135, 152, 194, 210, 223, 259, 357, 400, 478, 488, 668, 732, 733, 758, 828, 853, 1037; non-aqueous solvent systems – 67, 149, 166, 254, 548, 605; applications in chemical analysis – 390, 423; polymer aging – 64, 134, 207, 265, 552; photo initiators – no new reports; “inert” ion or molecule effect – 34, 35, 42, 75, 219,232, 260, 280, 443g, 592, 593, 661, 705, 773, 829, 915, 934, 947, 950, 987, 1093, 1102; dissolved metal ion effect – 50, 114, 116, 123, 124, 169, 170, 199, 233, 375, 452, 522, 553, 586, 813, 912, 1027; comparison with other advanced oxidation processes – 29, 43, 49, 149, 164, 175, 188, 192, 209, 230, 307, 407g, 462, 469, 534, 553, 638, 654, 660, 695, 697, 788g, 821, 830, 947, 948; purification of ultrapure water for recirculation –no new reports; clean room application – 236, 751, 1050g; purification of drinking water – 238, 260, 412, 465, 518, 664, 871, 875; municipal wastewater – 176, 574, 695, 874; process wastewater – 49, 174, 177, 209, 229, 264, 266, 316, 317, 328, 329, 396, 451, 489, 490, 546, 547, 571, 737, 874, 875, 911, 933, 936; chemical process air emissions – 469; paper mill effluent – 44, 1046; dairy waste – 616; organic synthesis – 166, 548, 605, 694, 847, 848, 849,988; surface science of TiO<sub>2</sub> or mixed oxides – 56, 63, 89, 119, 150, 186, 193, 309, 480, 481, 482, 497, 555g, 556g, 824, 1000; solid state NMR – no new reports; quantum yield or photonic efficiency –14, 74g, 78, 182, 183, 184, 201, 203, 217, 230, 344, 360, 361, 557, 680, 700, 752, 770, 776, 777, 778, 833g, 918g, 933g, 1054g; environmental application – 290, 407g, 461, 870, 875, 884, 1018g; indoor air quality applications – 185, 215, 238, 272g, 346, 407g, 599g, 633g, 663, 679, 698g, 745, 763, 854, 1047; humidity effect – 88, 89, 134, 196, 286g, 287g, 336g, 344g, 386g, 419g, 484g, 486g, 556g, 588g, 751g, 891g, 917g, 918g, 933g, 1021g, 1035g, 1087g, 1146g; microwave enhancement – 83; light flux dependence – 237, 265, 286g, 287g, 336g, 361, 386g, 444, 445, 460, 468, 486g, 499g, 585, 667g, 730, 870, 933g, 994, 995; light source effects – 37, 201, 216, 245, 269, 396, 412, 619, 648, 664, 688, 721, 760, 770, 788g, 963, 1002, 1042, 1126, 1140, 1145; solar experiment – 76,123,124,132, 150,



173, 216, 217, 218, 231, 259, 266, 267, 282, 290, 308, 331, 379, 396, 412, 426, 446, 454, 465, 543, 544, 545, 546, 547, 644, 645, 840, 906, 907, 908, 909, 911, 912, 942, 943, 944, 945, 1002, 1126; temperature effects – 177, 211g, 376g, 286g, 344g, 386g, 468, 509, 759, 917g, 918g, 919g, 1146g, 1148g; photoluminescence - 235; imaging applications – 422, 678; Dember effect – no new reports; self-cleaning surface – 55, 228, 338, 346, 347, 369, 383, 393, 408, 449, 514, 558, 588, 589, 590, 600, 627, 628, 668, 711, 721, 734, 735, 736, 745, 746, 803, 883, 923, 925, 954, 1036, 1065, 1066; ultrasound enhancement – 291, 821, 843, 844, 889; plasma enhancement – 304, 469; mixed waste - 321; catalyst lifetime/deactivation – 12g, 63g, 75, 143, 196, 265, 417g, 443g, 484, 511, 552, 588g, 628g, 662g, 663g, 676, 771, 903g, 917g, 1064; agglomeration/coagulation/sedimentation – 226, 227, 391, 814, 843, 844; treatment of photographic processing effluents – no new reports; point of zero charge – 222, 225, 226; electrorheology – no new reports; mechanism and intermediates – 2, 12g, 33, 35, 36, 52, 62, 97, 140, 142, 151, 191, 196g, 198g, 199, 201, 202, 203, 276, 312, 313, 336g, 376g, 390, 402g, 467, 478, 484g, 485g, 493, 494, 504, 505, 525, 526, 549, 555g, 556g, 583, 610g, 611g, 612g, 613g, 614g, 691, 696, 706, 734g, 735g, 736g, 775, 824, 872, 876, 888, 889, 949, 954, 978, 995, 1019g, 1054g, 1131; structure/property relationships – 285, 466, 942, 943, 1108, 1111; theoretical modeling – 324, 325, 504, 820, 1020, 1125; formation of hydroxyl radicals over metal oxides – 156, 360, 361; formulation of photocatalytic paint – 364, 564, 602; catalyst discovery and rapid screening of catalysts – 403, 731; enhancement of heat transfer using TiO<sub>2</sub> coatings – 859, 860; and photorechargeable battery - 1149.

## 2.6 Patents

The number of patents that cover aspects of photocatalytic technology is increasing rapidly. This report includes 1555 patents that have been added to the database since the last update. They cover a range of aqueous, gas-phase, and surface cleaning applications. The new patents are listed separately in Section 5.2. The citations for the patents have the date of issue in two formats. The first is day month year (e.g. 23 August 2001). The second is a numeric format in which the first four digits are the year, the next two digits are the month, and the final two digits are the day (e.g. 20000225 which is 25 February 2000). The numeric format is what is provided by database searches. The manual conversion of dates in the large numbers of patents became too burdensome.

## 2.7. Companies Active in the Field

R&D and market assessment activities continue at many companies in the United States, but there is little change in the list of companies that have started business lines that use photocatalytic processes.<sup>3</sup> Japanese companies are very aggressively commercializing applications of titanium dioxide catalysts, films, and coatings. These products have not yet begun to appear in the U.S. market. Pilkington plc and PPG Industries, Inc. have announced lines of self-cleaning flat glass for building exterior applications.



### 3.0 Compounds Studied

The tables in this section have the same format as those in the first two reports. No compounds have been removed from the tables, but new compounds have been added to the second table to incorporate new work. The list of the compounds included in various lists of priority pollutants, air toxics, and the toxic release inventory compiled by the EPA<sup>5</sup> provided the starting point for these tables. Table 1 lists compounds in the EPA categories; Table 2 lists organic compounds that are not in Table 1; and Table 3 covers inorganic compounds that have been treated by a photocatalytic process. The inorganic compounds are arranged by element unless a significant number of citations referred to work on a specific ion or compound. A few broad categories are included in Table 2 that reflect new applications: bacteria, algae, and viruses; coal or carbon; adsorbable organic halides (AOX); color or chemical oxygen demand (COD); and oil or petroleum, for example. In these tables the citation suffix “g” indicates a gas-phase study. The treatability of compounds that have not been tested can usually be inferred from results for related compounds in the tables.

**Table 1. Organic Compounds in EPA Lists of Priority Pollutants, Air Toxics, or Toxic Release Inventory**

Substance	Formula	Reference
1,1,1-Trichloroethane	CHCl <sub>2</sub> CH <sub>2</sub> Cl	106
1,1,2,2-Tetrachloroethane	CHCl <sub>2</sub> CHCl <sub>2</sub>	
1,1,2-Trichloroethane	CHCl <sub>2</sub> CH <sub>2</sub> Cl	
1,1,2-Trichloro-1,2,2-trifluoroethane	CCl <sub>2</sub> FCClF <sub>2</sub>	
1,1-Dichloroethane	CH <sub>3</sub> CHCl <sub>2</sub>	
1,1-Dimethyl hydrazine	(CH <sub>3</sub> ) <sub>2</sub> NNH <sub>2</sub>	
1,2,3-Trichloropropane	CH <sub>2</sub> ClCHClCH <sub>2</sub> Cl	
1,2,4-Trichlorobenzene	C <sub>6</sub> H <sub>3</sub> Cl <sub>3</sub>	
1,2,4-Trimethylbenzene	C <sub>6</sub> H <sub>3</sub> (CH <sub>3</sub> ) <sub>3</sub>	
1,2-Butylene oxide	H <sub>2</sub> COCHCH <sub>2</sub> CH <sub>3</sub>	
1,2-Dibromoethane	BrCH <sub>2</sub> CH <sub>2</sub> Br	
1,2-Dibromo-3-chloropropane (DBCP)	CH <sub>2</sub> BrCHBrCH <sub>2</sub> Cl	
1,2-Dichlorobenzene	C <sub>6</sub> H <sub>4</sub> Cl <sub>2</sub>	852,1088
1,2-Dichloroethane	ClCH <sub>2</sub> CH <sub>2</sub> Cl	1007,1093
1,2-Dichloroethylene	ClHC:CHCl	839,933g
1,2-Dichloropropane	CH <sub>3</sub> CHClCH <sub>2</sub> Cl	
1,2-Dinitrotoluene	C <sub>6</sub> H <sub>3</sub> CH <sub>3</sub> (NO <sub>2</sub> ) <sub>2</sub>	
1,2-Diphenylhydrazine	C <sub>12</sub> H <sub>12</sub> N <sub>2</sub>	
1,2-Trans-dichloroethene	C <sub>2</sub> H <sub>2</sub> Cl <sub>2</sub>	
1,3,5-Trinitrobenzene	C <sub>6</sub> H <sub>3</sub> (NO <sub>2</sub> ) <sub>3</sub>	
1,3-Butadiene	H <sub>2</sub> C:CHHC:CH <sub>2</sub>	
1,3-Dichlorobenzene	C <sub>6</sub> H <sub>4</sub> Cl	
1,3-Dichloropropene	CHCl:CHCH <sub>2</sub> Cl	
1,4-Dichlorobenzene	C <sub>6</sub> H <sub>4</sub> Cl <sub>2</sub>	
1,4-Dioxane	OCH <sub>2</sub> CH <sub>2</sub> OCH <sub>2</sub> CH <sub>2</sub>	
1-Amino-2-methylantraquinone	C <sub>6</sub> H <sub>4</sub> [C(O)] <sub>2</sub> C <sub>6</sub> H <sub>2</sub> NH <sub>2</sub> CH <sub>3</sub>	

<sup>5</sup> “Notice of the Second Priority List of Hazardous Substances Commonly Found at Superfund Sites,” *Environmental Reporter*, October 28, 1988, pp. 1255–1260.



**Table 1. Organic Compounds in EPA Lists of Priority Pollutants, Air Toxics, or Toxic Release Inventory**

Substance	Formula	Reference
1-Bromo-4-phenyloxybenzene	p-BrC <sub>6</sub> H <sub>4</sub> OC <sub>6</sub> H <sub>5</sub>	
2,2,4-Trimethylpentane	(CH <sub>3</sub> ) <sub>3</sub> C <sub>5</sub> H <sub>9</sub>	
2,3,7,8-Tetrachlorodibenzo-p-dioxin	C <sub>12</sub> H <sub>4</sub> Cl <sub>4</sub> O <sub>2</sub>	
2,4,5-Trichlorophenoxyacetic acid	C <sub>6</sub> H <sub>2</sub> Cl <sub>3</sub> OCH <sub>2</sub> CO <sub>2</sub> H	
2,4,5-TP acid (silvex)	Cl <sub>3</sub> C <sub>6</sub> H <sub>2</sub> OCH(CH <sub>3</sub> )CO <sub>2</sub> H	
2,4,5-Trichlorophenol	C <sub>6</sub> H <sub>2</sub> Cl <sub>3</sub> OH	
2,4,6-Trichlorophenol	C <sub>6</sub> H <sub>2</sub> Cl <sub>3</sub> OH	152,153,154,155,157,162, 182,710
2,4,6-Trinitrotoluene	CH <sub>3</sub> C <sub>6</sub> H <sub>2</sub> (NO <sub>2</sub> ) <sub>3</sub>	175,220,758,759,760
2,4-Diaminoanisole	(NH <sub>2</sub> ) <sub>2</sub> C <sub>6</sub> H <sub>3</sub> OCH <sub>3</sub>	
2,4-Dichlorophenoxyacetic acid (2,4-D)	Cl <sub>2</sub> C <sub>6</sub> H <sub>3</sub> OCH <sub>2</sub> COOH	312
2,4-Diaminoanisole sulfate	(NH <sub>2</sub> ) <sub>2</sub> C <sub>6</sub> H <sub>3</sub> OCH <sub>3</sub> ·H <sub>2</sub> SO <sub>4</sub>	
2,4-Dichlorophenol	Cl <sub>2</sub> C <sub>6</sub> H <sub>3</sub> OH	189,267,594,710,775,886, 887,982
2,4-Dimethylphenol	(CH <sub>3</sub> ) <sub>2</sub> C <sub>6</sub> H <sub>3</sub> OH	
2,4-Dinitrophenol	C <sub>6</sub> H <sub>3</sub> OH(NO <sub>2</sub> ) <sub>2</sub>	335,488
2,4-Dinitrotoluene	C <sub>6</sub> H <sub>3</sub> CH <sub>3</sub> (NO <sub>2</sub> ) <sub>2</sub>	758
2,4-Toluene diamine	CH <sub>3</sub> (NH <sub>2</sub> ) <sub>2</sub> C <sub>6</sub> H <sub>3</sub>	
2,6-Dinitrotoluene	C <sub>6</sub> H <sub>3</sub> CH <sub>3</sub> (NO <sub>2</sub> ) <sub>2</sub>	
2,6-Xylidine	(CH <sub>3</sub> ) <sub>2</sub> C <sub>6</sub> H <sub>3</sub> NH <sub>2</sub>	
2-Acetylaminofluorene	CH <sub>3</sub> C(O)NHC <sub>6</sub> H <sub>3</sub> CH <sub>2</sub> C <sub>6</sub> H <sub>4</sub>	
2-Aminoanthraquinone	C <sub>6</sub> H <sub>4</sub> (CO) <sub>2</sub> C <sub>6</sub> H <sub>3</sub> NH <sub>2</sub>	
2-Butanone	CH <sub>3</sub> COCH <sub>2</sub> CH <sub>3</sub>	
2-Chloroacetophenone	C <sub>6</sub> H <sub>5</sub> COCH <sub>2</sub> Cl	
2-Chloroethyl vinyl ether	CH <sub>2</sub> ClCH <sub>2</sub> OCHCH <sub>2</sub>	
2-Chlorophenol	C <sub>6</sub> H <sub>4</sub> OHCl	83,114,189,331,479,522, 724,931
2-Ethoxyethanol	H <sub>3</sub> CCH <sub>2</sub> OCH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> OH	
2-Methoxyethanol	MeOCH <sub>2</sub> CH <sub>2</sub> OH	
2-Methylnaphthalene	C <sub>10</sub> H <sub>7</sub> CH <sub>3</sub>	
2-Nitrophenol	NO <sub>2</sub> C <sub>6</sub> H <sub>4</sub> OH	285, 931
2-Nitropropane	CH <sub>3</sub> CHNO <sub>2</sub> CH <sub>3</sub>	
2-Pentanone, 4-Methyl	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> COCH <sub>3</sub>	
2-Phenylphenol	C <sub>6</sub> H <sub>5</sub> C <sub>6</sub> H <sub>4</sub> OH	
3,3'-Dichlorobenzidine	C <sub>6</sub> H <sub>3</sub> CINH <sub>2</sub> C <sub>6</sub> H <sub>3</sub> CINH <sub>2</sub>	
3,3'-Dimethoxybenzidine	[C <sub>6</sub> H <sub>3</sub> (OCH <sub>3</sub> )NH <sub>2</sub> ] <sub>2</sub>	
3,3'-Dimethylbenzidine (o-Tolidine)	[C <sub>6</sub> H <sub>3</sub> (CH <sub>3</sub> )NH <sub>2</sub> ] <sub>2</sub>	
4,4'-Dichlorodiphenyldichloroethylene	(ClC <sub>6</sub> H <sub>4</sub> ) <sub>2</sub> CCCl <sub>2</sub>	
4,4'-Diaminodiphenyl ether	NH <sub>2</sub> (C <sub>6</sub> H <sub>4</sub> ) <sub>2</sub> NH <sub>2</sub>	
4,4'-Isopropylidenediphenol	(CH <sub>3</sub> ) <sub>2</sub> C(C <sub>6</sub> H <sub>4</sub> OH) <sub>2</sub>	
4,4'-Methylenebis(N,N-dimethyl)benzenamine	C <sub>17</sub> H <sub>22</sub> N <sub>2</sub>	
4,4'-Methylenedianiline	H <sub>2</sub> NC <sub>6</sub> H <sub>4</sub> CH <sub>2</sub> C <sub>6</sub> H <sub>4</sub> NH <sub>2</sub>	
4,4'-Methylene-bis-(2-chloroaniline)	CH <sub>2</sub> (C <sub>6</sub> H <sub>4</sub> CINH <sub>2</sub> ) <sub>2</sub>	



**Table 1. Organic Compounds in EPA Lists of Priority Pollutants, Air Toxics, or Toxic Release Inventory**

Substance	Formula	Reference
4,4'-Thiodianiline	C <sub>12</sub> H <sub>12</sub> N <sub>2</sub> S	
4,6-Dinitro-o-cresol	CH <sub>3</sub> C <sub>6</sub> H <sub>2</sub> (NO <sub>2</sub> ) <sub>2</sub> OH	
4,6-Dinitro-2-methylphenol	C <sub>7</sub> H <sub>6</sub> N <sub>2</sub> O <sub>5</sub>	
4-Aminoazobenzene	C <sub>6</sub> H <sub>5</sub> NNC <sub>6</sub> H <sub>4</sub> NH <sub>2</sub>	268
4-Aminobiphenyl	C <sub>6</sub> H <sub>5</sub> C <sub>6</sub> H <sub>4</sub> NH <sub>2</sub>	
4-Chloroaniline	ClC <sub>6</sub> H <sub>4</sub> NH <sub>2</sub>	36
4-Chlorophenyl phenyl ether	p-ClC <sub>6</sub> H <sub>4</sub> OC <sub>6</sub> H <sub>5</sub>	
4-Dimethylaminoazobenzene	(CH <sub>3</sub> ) <sub>2</sub> C <sub>6</sub> H <sub>3</sub> NH <sub>2</sub>	
4-Methylphenol	p-CH <sub>3</sub> C <sub>6</sub> H <sub>4</sub> OH	140
4-Nitrobiphenyl	C <sub>6</sub> H <sub>5</sub> C <sub>6</sub> H <sub>4</sub> NO <sub>2</sub>	
4-Nitrophenol	NO <sub>2</sub> C <sub>6</sub> H <sub>4</sub> OH	15,104,285,519,551,554, 606,770
5-Nitro-o-anisidine	NO <sub>2</sub> C <sub>6</sub> H <sub>3</sub> (NH <sub>2</sub> )(OCH <sub>3</sub> )	
Acenaphthene	C <sub>10</sub> H <sub>6</sub> (CH <sub>2</sub> ) <sub>2</sub>	
Acenaphthylene	C <sub>12</sub> H <sub>8</sub>	
Acetaldehyde	CH <sub>3</sub> CHO	31g,52g,165g,367g,371g, 434g,525g,526g,610g,657g 658g,663g,667g,669g,670g 802g,904,991g,1038
Acetamide	CH <sub>3</sub> CNOH <sub>2</sub>	
Acetone	CH <sub>3</sub> COCH <sub>3</sub>	198g,286g,386g,525g,783g 784g,802g,861g,917g,918g 919g,920g,972g,1078g, 1146g,1147g
Acetonitrile	CH <sub>3</sub> CN	1144
Acetophenone	CH <sub>3</sub> C(O)C <sub>6</sub> H <sub>5</sub>	994,995,997
Acrolein	CH <sub>2</sub> CHCHO	
Acrylamide	CH <sub>2</sub> CHCONH <sub>2</sub>	
Acrylic acid	H <sub>2</sub> C:CHCOOH	42
Acrylonitrile	H <sub>2</sub> C:CHCN	
Aldrin	C <sub>12</sub> H <sub>8</sub> Cl <sub>6</sub>	
Allyl chloride	H <sub>2</sub> CCHCH <sub>2</sub> Cl	
Aniline	C <sub>6</sub> H <sub>5</sub> NH <sub>2</sub>	36,38,305,478,714,754
Anthracene	C <sub>6</sub> H <sub>4</sub> (CH) <sub>2</sub> C <sub>6</sub> H <sub>4</sub>	691
Aramite	(CH <sub>3</sub> ) <sub>3</sub> CC <sub>6</sub> H <sub>4</sub> OCH <sub>2</sub> CH(CH <sub>3</sub> )- SO <sub>3</sub> C <sub>2</sub> H <sub>4</sub> Cl	
Atrazine	C <sub>18</sub> H <sub>14</sub> ClN <sub>5</sub>	307,886,887,888
Benzal chloride	C <sub>6</sub> H <sub>5</sub> CHCl <sub>2</sub>	
Benzamide	C <sub>6</sub> H <sub>5</sub> CONH <sub>2</sub>	306,699,725,726
Benzene	C <sub>6</sub> H <sub>6</sub>	77g,151g,195g,196g,234g, 416g,648,698g,840,903g, 1049g,1055g





**Table 1. Organic Compounds in EPA Lists of Priority Pollutants, Air Toxics, or Toxic Release Inventory**

Substance	Formula	Reference
Benzidine	$\text{NH}_2(\text{C}_6\text{H}_4)_2\text{NH}_2$	
Benzoic acid	$\text{C}_6\text{H}_5\text{COOH}$	1108,1111
Benzoic trichloride	$\text{C}_6\text{H}_5\text{CCl}_3$	
Benzoyl chloride	$\text{C}_6\text{H}_5\text{COCl}$	
Benzoyl peroxide	$(\text{C}_6\text{H}_5\text{CO})_2\text{O}_2$	
Benzo(a)anthracene	$\text{C}_{22}\text{H}_{14}$	
Benzo(a)pyrene	$\text{C}_{20}\text{H}_{12}$	
Benzo(b)fluoranthene	$\text{C}_{20}\text{H}_{12}$	
Benzo(g,h,i) perylene	$\text{C}_{22}\text{H}_{12}$	
Benzyl alcohol	$\text{C}_6\text{H}_5\text{CH}_2\text{OH}$	
Benzyl chloride	$\text{C}_6\text{H}_5\text{CH}_2\text{Cl}$	
BHC (Benzenehexachloride)	$\text{C}_6\text{H}_6\text{Cl}_6$	
Biphenyl	$\text{C}_6\text{H}_5\text{C}_6\text{H}_5$	
Bis(2-Chloroethoxy)methane	$\text{CH}_2(2\text{-ClC}_2\text{H}_5\text{O})_2$	
Bis(2-chloroethyl) ether	$\text{ClCH}_2\text{CH}_2\text{OCH}_2\text{CH}_2\text{Cl}$	
Bis(2-chloro-1-methylethyl) ether	$[\text{ClCH}_2(\text{CH}_3)\text{CH}]_2\text{O}$	
Bis(2-ethylhexyl) adipate	$(\text{C}_7\text{H}_{13})_2\text{C}_4\text{H}_8(\text{CO}_2)_2$	
Bis(2-ethylhexyl)phthalate	$(\text{C}_4\text{H}_9\text{CH}(\text{CH}_2))_2\text{OOC}$	
Bis(chloromethyl)ether	$(\text{CH}_2\text{Cl})\text{O}(\text{CH}_2\text{Cl})$	
Bromochloromethane	$\text{BrCH}_2\text{Cl}$	
Bromodichloromethane	$\text{CHCl}_2\text{Br}$	
Bromoethane	$\text{C}_2\text{H}_5\text{Br}$	
Bromoform (Tribromomethane)	$\text{CHBr}_3$	82,1051,1052
Bromomethane (Methyl bromide)	$\text{CH}_3\text{Br}$	82,234g
Butyl acrylate	$\text{CH}_2:\text{CHCOOC}_4\text{H}_9$	
Butylbenzyl phthalate	$\text{C}_4\text{H}_9\text{OOC C}_6\text{H}_4\text{COOC}_7\text{H}_7$	
Butyraldehyde	$\text{CH}_3(\text{CH}_2)_2\text{CHO}$	52g
Calcium cyanamide	$\text{NCN Ca}$	
Caprolactam	$\text{CH}_2(\text{CH}_2)_4\text{NHCO}$	
Captan (N-Trichloromethylmercapto-tetrahydrophthalimide)	$\text{C}_9\text{H}_8\text{Cl}_3\text{NO}_2\text{S}$	
Carbaryl [1-Naphthalenol, methylcarbamate]	$\text{C}_{10}\text{H}_7\text{OOCNHCH}_3$	705
Carbon disulfide	$\text{CS}_2$	
Carbon tetrachloride	$\text{CCl}_4$	106,131,594,817,838
Carbonyl sulfide	$\text{COS}$	
Catechol	$\text{C}_6\text{H}_4(\text{OH})_2$	853
Chloramben (Benzoic acid, 3-amino-2,5-dichloro-)	$\text{C}_6\text{H}(\text{CO}_2\text{H})(\text{NH}_2)\text{Cl}_2$	707
Chlordane	$\text{C}_{10}\text{H}_6\text{Cl}_8$	
Chloroacetic acid	$\text{CH}_2\text{ClCOOH}$	440,441,830
Chlorobenzene	$\text{C}_6\text{H}_5\text{Cl}$	288g
Chlorobenzilate (Benzeneacetic acid, 4-chloro-alpha-(4-chlorophenyl)-)	$(\text{C}_6\text{H}_4\text{Cl})_2\text{C}(\text{OH})\text{COOC}_2\text{H}_5$	



**Table 1. Organic Compounds in EPA Lists of Priority Pollutants, Air Toxics, or Toxic Release Inventory**

Substance	Formula	Reference
Chlorodibenzodioxins, various	$C_{12}O_2H_{8-x}Cl_x$	132
Chlorodibenzofurans	$C_{12}OH_{8-x}Cl_x$	
Chlorodibromomethane	$ClBr_2CH$	
Chlorodifluoromethane	$CHClF_2$	
Chloroethane	$C_2H_5Cl$	
Chloroform	$CHCl_3$	9g, 106, 112, 113, 333, 385, 518
Chloromethane	$CH_3Cl$	
Chloromethyl methyl ether	$C_2H_5ClO$	
Chloroprene	$H_2C:CHCl:CH_2$	
Chlorothalonil (1,3-Benzenededicarbonitrile, 2,4,5,6-tetrachloro-)	$C_6Cl_4(CN)_2$	
Chrysene	$C_{18}H_{12}$	
cis-1,2-Dichloroethylene	$ClHC:CHCl$	
cis-1,3-Dichloropropene	$CHCl:CHCH_2Cl$	
o-,m-,p-Cresols	$CH_3C_6H_4OH$	692
Cumene	$C_6H_5CH(CH_3)_2$	
Cumene hydroperoxide	$C_6H_5C(CH_3)_2OOH$	
Cupferron (Benzeneamine, N-hydroxy-N-nitrose, ammonium salt)	$C_6H_5N(NO)ONH_4$	
Cyclohexane	$C_6H_{12}$	548,605
Cyclohexanone	$C_6H_{10}O$	
Cyclonite (RDX)	$(CH_2)_3(NNO_2)_3$	
Decabromodiphenyl oxide	$(C_6Br_5)_2O$	
Dialate [Carbamothioic acid, bis (1-methylethyl)-, S-(2,3-dichloro-2-propenyl) ester]	$[(CH_3)_2CH]_2NCOSCH_2CClCHCl$	
Diaminotoluene (mixed isomers)	$CH_3C_6H_3(NH_2)_2$	
Diazomethane	$CH_2N_2$	
Dibenzofuran	$C_{12}H_8O$	
Dibenzo(a,h)anthracene	$C_{22}H_{14}$	
Dibromochloropropane	$CH_2BrCHBrCH_2Cl$	
Dibutyl phthalate	$C_6H_4[C(O)OC_4H_9]_2$	1056
Dichlorobenzene (mixed isomers)	$C_6H_4Cl_2$	838
Dichlorobromomethane	$CHBrCl_2$	
Dichlorodifluoromethane	$CCl_2F_2$	
Dichlorvos (Phosphoric acid, 2-dichloroethenyl dimethyl ester)	$(CH_3O)_2P(O)OCH:CCl_2$	45, 118, 491, 1026, 1028
Dicofol (4,4'-Dichloro-alpha-trichloro-Methylbenzhydrol)	$C_{14}H_9Cl_5O$	
Dieldrin/aldrin	$C_{12}H_{10}OPCl_6$	737
Diepoxybutane	$C_4H_6O_2$	
Diethanolamine	$(HOCH_2CH_2)_2NH$	426,427



**Table 1. Organic Compounds in EPA Lists of Priority Pollutants, Air Toxics, or Toxic Release Inventory**

Substance	Formula	Reference
Diethyl phthalate	$C_6H_4(CO_2C_2H_5)_2$	
Diethyl sulfate	$(C_2H_5)_2SO_4$	
Dimethyl aminoazobenzene	$C_6H_5NNC_6H_4N(CH_3)_2$	
Dimethyl formamide (DMF)	$HCON(CH_3)_2$	
Dimethyl phthalate	$C_6H_4(COOCH_3)_2$	
Dimethyl sulfate	$(CH_3)_2SO_4$	
Dimethylcarbanyl chloride	$(CH_3)_2NCOCl$	
Disulfoton	$(C_2H_5O)_2P(S)SCH_2CH_2SCH_2CH_3$	
Di-n-butyl phthalate	$C_6H_4(COOC_4H_9)_2$	
Di-n-octyl phthalate	$C_6H_4(CO_2)(n-C_8H_{17})_2$	
Di-(2-ethylhexy) phthalate (DEHP)	$C_6H_4[COOCH_2CH(C_2H_5)C_4H_9]_2$	
Endosulfan	$C_9H_6Cl_6O_3S$	
Endrin aldehyde/ endrin	$(C_{12}H_8OCl_6)$	
Epichlorohydrin	$CH_2OCHCH_2Cl$	
Ethyl acrylate	$CH_2:CHCOOC_2H_5$	
Ethyl chloroformate	$ClCOOC_2H_5$	
Ethylbenzene	$C_6H_5C_2H_5$	839,840
Ethylene	$H_2CCH_2$	234g,270g,373g,693g,810g 891g,1020g,1021g,1148g
Ethylene glycol	$CH_2OHCH_2OH$	452
Ethylene oxide	$CH_2CH_2O$	
Ethylene thiourea	$NHCH_2CH_2NHCS$	
Ethyleneimine (Aziridine)	$CH_2NHCH_2$	
Fluometuron [Urea, N,N-dimethyl-N'-[3-(trifluoromethyl)phenyl]-]	$C_{10}H_{11}F_3N_2O$	
Fluoranthene	$C_{16}H_{10}$	734g,736g
Fluorene	$C_6H_4CH_2C_6H_4$	
Fluorotrichloromethane	$CCl_3F$	
Formaldehyde	$HCHO$	185g,245g,603g,743g,744g 807,1032
Heptachlor/heptachlor epoxide	$C_{10}H_7Cl_7$	
Heptane	$CH_3(CH_2)_5CH_3$	190g
Hexachlorobenzene	$C_6Cl_6$	
Hexachlorobutadiene	$Cl_2C:CCICCl:CCl_2$	
Hexachlorocyclopentadiene	$C_5Cl_6$	
Hexachloroethane	$Cl_3CCCl_3$	
Hexachloronaphthalene	$C_{10}H_2Cl_6$	
Hexamethylphosphoramide	$[(N(CH_3)_2)_3PO$	
Hexamethylene-1,6-diisocyanate	$OCN(CH_2)_6NCO$	
Hexane	$CH_3(CH_2)_4CH_3$	
Hydroquinone	$C_6H_4(OH)_2$	285,479,494,811
Indeno(1,2,3-cd)pyrene	$C_{22}H_{12}$	
Isophorone	$C(O)CHC(CH_3)CH_2C(CH_3)_2CH_2$	



**Table 1. Organic Compounds in EPA Lists of Priority Pollutants, Air Toxics, or Toxic Release Inventory**

Substance	Formula	Reference
Isopropyl alcohol	$(\text{CH}_3)_2\text{CHOH}$	72g, 100g, 235, 286g, 292, 293, 349g, 593, 647, 667g, 775, 833g, 972g, 1007, 1010, 1011
Lindane(gamma-Benzenehexachloride)	$\text{C}_6\text{H}_6\text{Cl}_6$	76, 182, 1095, 1096
Malachite Green	$\text{C}_{23}\text{H}_{25}\text{ClN}_2$	
Malathion	$(\text{CH}_3\text{O})_2\text{P}(\text{S})\text{SCH}(\text{CO}_2\text{C}_2\text{H}_5)\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5$	
Maleic anhydride	$\text{HC}:\text{CHC}(\text{O})\text{OC}(\text{O})$	
Maneb (Carbamodithioic acid, 1,2-ethanediybis-, manganese complex)	$(\text{SSCNCH}_2\text{CH}_2\text{NHCSS})\text{Mn}$	
Mechlorethamine	$\text{CH}_3\text{N}(\text{CH}_2\text{CH}_2\text{Cl})_2$	
Melamine	$\text{H}_2\text{NCNC}(\text{NH}_2)\text{NC}(\text{NH}_2)\text{N}$	
Methanol	$\text{CH}_3\text{OH}$	110, 112, 113, 171, 403, 608, 817, 849, 926, 972g, 988, 1095, 1096
Methoxychlor	$\text{Cl}_3\text{CCH}(\text{C}_6\text{H}_4\text{OCH}_3)_2$	
Methyl acrylate	$\text{CH}_2:\text{CHCOOCH}_3$	
Methyl butyl ketone	$\text{CH}_3\text{COC}_4\text{H}_9$	
Methyl ethyl ketone	$\text{CH}_3\text{COCH}_2\text{CH}_3$	838
Methyl iodide	$\text{CH}_3\text{I}$	
Methyl isobutyl ketone	$(\text{CH}_3)_2\text{CHCOCH}_3$	
Methyl isocyanate	$\text{CH}_3\text{NCO}$	
Methyl methacrylate	$\text{CH}_2:\text{C}(\text{CH}_3)\text{COOCH}_3$	
Methyl tert-butyl ether	$(\text{CH}_3)_3\text{COCH}$	660
Methylene bromide	$\text{CH}_2\text{Br}_2$	82
Methylene chloride	$\text{CH}_2\text{Cl}_2$	9g
Methylenebis(phenylisocyanate) (MBI)	$\text{CH}_2(\text{C}_6\text{H}_4\text{NCO})_2$	
Methylhydrazine	$\text{CH}_3\text{NHNH}_2$	
Michler's ketone	$\text{CO}[\text{C}_6\text{H}_4\text{N}(\text{CH}_3)_2]_2$	
Mirex	$\text{C}_{10}\text{Cl}_{12}$	
Mustard gas	$\text{S}(\text{CH}_2\text{CH}_2\text{Cl})_2$	
m-Nitroaniline	$\text{NO}_2\text{C}_6\text{H}_4\text{NH}_2$	
N,N-Dimethylaniline	$\text{C}_6\text{H}_5\text{N}(\text{CH}_3)_2$	
Naphthalene	$\text{C}_{10}\text{H}_8$	380, 691
Naphthylamine (alpha-, beta-)	$\text{C}_{10}\text{H}_7\text{NH}_2$	
Nitrilotriacetic acid	$\text{N}(\text{CH}_2\text{COOH})_3$	317
Nitrobenzene	$\text{C}_6\text{H}_5\text{NO}_2$	478, 541, 548
Nitrofen [Benzene, 2,4-dichloro-1-(4-nitrophenoxy)-]	$\text{C}_{12}\text{H}_7\text{Cl}_2\text{NO}_3$	
Nitrogen mustard (2-Chloro-N-(2-chloroethyl)-N-methylethanamine)	$(\text{ClCH}_2\text{CH}_2)_2\text{NCH}_3$	
Nitroglycerin	$\text{CH}_2\text{NO}_3\text{CHNO}_3\text{CH}_2\text{NO}_3$	619
Nitrophenol	$\text{NO}_2\text{C}_6\text{H}_4\text{OH}$	



**Table 1. Organic Compounds in EPA Lists of Priority Pollutants, Air Toxics, or Toxic Release Inventory**

Substance	Formula	Reference
n-Butyl alcohol	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> CH <sub>2</sub> OH	
n-Dioctyl phthalate	(C <sub>8</sub> H <sub>17</sub> OOC) <sub>2</sub> C <sub>6</sub> H <sub>4</sub>	236
N-Nitrosodiethylamine	C <sub>4</sub> H <sub>10</sub> N <sub>2</sub> O	
N-Nitrosodimethylamine	(CH <sub>3</sub> ) <sub>2</sub> N <sub>2</sub> O	
N-Nitrosodiphenylamine	(C <sub>6</sub> H <sub>5</sub> ) <sub>2</sub> NNO	
N-Nitrosodi-n-butylamine	ONN(n-C <sub>4</sub> H <sub>9</sub> ) <sub>2</sub>	
N-Nitrosodi-n-propylamine	ONN(n-C <sub>3</sub> H <sub>7</sub> ) <sub>2</sub>	
N-Nitrosomethylvinylamine	ONN(CH <sub>3</sub> )(C <sub>2</sub> H <sub>3</sub> )	
N-Nitrosomorpholine	ONNC <sub>4</sub> H <sub>8</sub> O	
N-Nitrosonoronicotine		
N-Nitrosopiperidine	C <sub>5</sub> H <sub>10</sub> NHNO	
N-Nitroso-N-ethylurea	C(O)(NH <sub>2</sub> )N(NO)C <sub>2</sub> H <sub>5</sub>	
N-Nitroso-N-methylurea	C(O)(NH <sub>2</sub> )N(NO)(CH <sub>3</sub> )	
n-Pentane	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>3</sub> CH <sub>3</sub>	
Octachloronaphthalene	C <sub>10</sub> Cl <sub>8</sub>	
Octane	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>6</sub> CH <sub>3</sub>	698g
Oxirane	H <sub>2</sub> COCH <sub>2</sub>	
o-Anisidine	CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub> NH <sub>2</sub>	
o-Anisidine hydrochloride	CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub> NH <sub>2</sub> .HCl	
o-Nitroaniline	NO <sub>2</sub> C <sub>6</sub> H <sub>4</sub> NH <sub>2</sub>	
o-Toluidine	CH <sub>3</sub> C <sub>6</sub> H <sub>4</sub> NH <sub>2</sub>	
o-Toluidine hydrochloride	CH <sub>3</sub> C <sub>6</sub> H <sub>4</sub> NH <sub>2</sub> .HCl	
Parathion (DNTP)	(C <sub>2</sub> H <sub>5</sub> O) <sub>2</sub> P(S)OC <sub>6</sub> H <sub>4</sub> NO <sub>2</sub>	
PCBs (Aroclor 1260,1254,1248, 1242)	C <sub>12</sub> Cl <sub>x</sub> H <sub>10-x</sub>	254,339
Pentachlorobenzene	C <sub>6</sub> Cl <sub>5</sub> H	
Pentachlorophenol	C <sub>6</sub> Cl <sub>5</sub> OH	710,775,965,983,984
Peracetic acid	CH <sub>3</sub> COOOH	
Phenanthrene	C <sub>14</sub> H <sub>10</sub>	1088
Phenol	C <sub>6</sub> H <sub>5</sub> OH	54,90,91,92,93,98,102, 104,136,145,161,167,168, 179,180,182,193,194,201, 202,203,210,212,217,223, 260,267,276,278,283,284, 284, 383,396,433,454,466, 471,479,559,560,577,592, 593,594,625,727,776,777, 778,831,886,887,890,898, 899, 915,963, 974,978,979 980,981,1104,1113,1114, 1133,1134
Phenol,2-methyl	CH <sub>3</sub> C <sub>6</sub> H <sub>4</sub> OH	
Phosgene	COCl <sub>2</sub>	
Phthalic anhydride	C <sub>6</sub> H <sub>4</sub> (CO) <sub>2</sub> O	42
Picric acid	C <sub>6</sub> H <sub>2</sub> (NO <sub>2</sub> ) <sub>3</sub> OH	



**Table 1. Organic Compounds in EPA Lists of Priority Pollutants, Air Toxics, or Toxic Release Inventory**

Substance	Formula	Reference
Polybrominatedbiphenyls	$C_{12}Br_xH_{10-x}$	
Propane sultone	$C_3H_6SO_2$	
Propionaldehyde	$C_2H_5CHO$	861g,1051g
Propiolactone, beta-	$OCH_2CH_2CO$	
Propoxur [Phenol, 2-(1-methylethoxy)-methylcarbamate]	$C_{11}H_{15}NO_3$	520,521,756
Propylene oxide	$CH_2OCHCH_3$	
Propylene (Propene)	$CH_3CH:CH_2$	1057g
Propyleneimine	$CH_3HCNHCH_2$	
Pyrene	$C_{16}H_{10}$	
p-Anisidine	$CH_3OC_6H_4NH_2$	
p-Chloro-m-cresol	$C_6H_3CH_3OHCl$	
p-Cresidine	$CH_3C_6H_3(NH_2)OCH_3$	
p-Nitrosodiphenylamine	$(C_6H_5)_2NNO$	
p-Phenylenediamine	$C_6H_4(NH_2)_2$	
Quinoline	$C_9H_7N$	97
Quinone	$C_6H_4O_2$	
Quintozene (Pentachloronitrobenzene)	$C_6Cl_5NO_2$	
Safrole	$C_3H_5C_6H_3O_2CH_2$	
sec-Butyl alcohol	$CH_3CH_2CHOHCH_3$	
Sevin (carbaryl)	$C_{10}H_7OOCNHCH_3$	
Sodium Alizarinsulfonate	$SO_3C_6H_3(CO)_2C_6H_2(OH)_2Na$	
Styrene	$C_6H_5CH:CH_2$	
Styrene oxide	$C_6H_5CHOCH_2$	
Terephthalic acid	$C_6H_4(COOH)_2$	360,361
tert-Butyl alcohol	$(CH_3)_3COH$	593
tert-Butylformate	$(CH_3)_3COC(O)H$	
Tetrachloroethylene	$Cl_2C:CCl_2$	9g,244g,287g,373g,486g,515g,617g,618g,634,773,838,839,1018g,1058g,312
Tetrachlorvinphos	$C_{10}H_0Cl_4O_4P$	
Tetrahydrofuran	$CH_2CH_2CH_2CH_2O$	
Thioacetamide	$CH_3CSNH_2$	
Thiourea	$(NH_2)_2CS$	
Toluene	$C_6H_5CH_3$	12g,35,63g,117,151g,286g,344g,394g,486g,540g,555g,556g,633g,839,840,686
Toluene diisocyanate	$CH_3C_6H_3(NCO)_2$	
Toxaphene	$C_{10}H_{10}Cl_8$	
Triaziquone	$C_{12}H_{13}N_3O_2$	
Trichlorfon	$(CH_3O)_2P(O)CH(OH)CCl_3$	



**Table 1. Organic Compounds in EPA Lists of Priority Pollutants, Air Toxics, or Toxic Release Inventory**

Substance	Formula	Reference
Trichloroethylene	CHCl:CCl <sub>2</sub>	9g,10,74g,75,78,94g,102 112,113,158g,211g,287g, 373g,388g,389g,417g, 419g,420g,421g,476g, 484g,485g,539g,608,618g, 687,723g,753g,839,898, 962g,1018g,1019g,1054g, 1055g,1087g
Triethylamine	N(C <sub>2</sub> H <sub>5</sub> ) <sub>3</sub>	775
Trifluralin	F <sub>3</sub> C(NO <sub>2</sub> ) <sub>2</sub> C <sub>6</sub> H <sub>2</sub> N(C <sub>3</sub> H <sub>7</sub> ) <sub>2</sub>	
Trinitrophenylmethylnitramine	(NO <sub>2</sub> ) <sub>3</sub> C <sub>6</sub> H <sub>2</sub> N(NO <sub>2</sub> )CH <sub>3</sub>	
Tris(2,3-dibromopropyl) phosphate	(CH <sub>2</sub> BrCHBrCH <sub>2</sub> O) <sub>3</sub> PO	
Urethane (ethyl carbamate)	CO(NH <sub>2</sub> )OC <sub>2</sub> H <sub>5</sub>	
Vinyl acetate	CH <sub>3</sub> COOCH:CH <sub>2</sub>	
Vinyl bromide	CH <sub>2</sub> CHBr	
Vinyl chloride	CH <sub>2</sub> :CHCl	
Vinylidene chloride	CH <sub>2</sub> :CCl <sub>2</sub>	
Xylene (mixed isomers)	C <sub>6</sub> H <sub>4</sub> (CH <sub>3</sub> ) <sub>2</sub>	698g,839,840
Zineb	Zn(CS <sub>2</sub> NHCH <sub>2</sub> ) <sub>2</sub>	

**Table 2. Other Organic Compounds Treated by a Photocatalytic Process**

Substance	Formula	Reference
1,1,1,2-Tetrachloroethane	$\text{Cl}_3\text{CCH}_2\text{Cl}$	
1,1,1,2-Tetrafluoroethane	$\text{F}_3\text{CCH}_2\text{F}$	
1,3,5,7-Tetramethylcyclotetrasiloxane		
1,1,1-Trifluoro-2,2,2-trichloroethane	$\text{F}_3\text{CCCl}_3$	
1,1,1-Trifluorobromochloroethane	$\text{C}_2\text{HF}_3\text{ClBr}$	
1,1,3-Trichloropropene	$\text{Cl}_2\text{CCHCH}_2\text{Cl}$	
1,1-Difluoro-1,2,2-trichloroethane	$\text{ClF}_2\text{CCHCl}_2$	
1,1-Difluoro-1,2-dichloroethane	$\text{FCICCClH}_2$	
1,1-Difluoroethylene	$\text{CH}_2\text{CF}_2$	
1,1-Dimethyl-3-phenylurea	$\text{C}_6\text{H}_5\text{NHC(O)N(CH}_3)_2$	
1,1-Diphenylethylene	$(\text{C}_6\text{H}_5)\text{CCH}_2$	
1,2-Dimethoxybenzene	$(\text{CH}_3\text{O})_2\text{C}_6\text{H}_4$	
1,2-Bis(2-chloroethoxy)ethane	$(\text{ClC}_2\text{H}_4)_2\text{C}_2\text{H}_4$	
1,2,3-Benzenetricarboxylic acid (Hemimellitic acid)	$\text{C}_6\text{H}_3(\text{CO}_2\text{H})_3$	33
1,2-, 1,3-, or 1,4-Dinitrobenzene	$(\text{NO}_2)_2\text{C}_6\text{H}_4$	
1,2,4-Benzenetricarboxylic acid (Trimellitic acid)	$\text{C}_6\text{H}_3(\text{CO}_2\text{H})_3$	33
1,2,4-Trihydroxybenzene	$\text{C}_6\text{H}_3(\text{OH})_3$	853
1,2,4-Trinitrobenzene	$\text{C}_6\text{H}_3(\text{NO}_2)_2$	
1,3,5-Trinitrobenzene	$\text{C}_6\text{H}_3(\text{NO}_2)_2$	
1,2,4,5-Benzenetetracarboxylic acid (Pyromellitic acid)	$\text{C}_6\text{H}_2(\text{CO}_2\text{H})_4$	33
1,2,4,5-Tetramethylbenzene	$(\text{CH}_3)_4\text{C}_6\text{H}_2$	
1,3-Dihydroxybenzene	$(\text{OH})_2\text{C}_6\text{H}_4$	680
1,3-Dimethoxybenzene	$(\text{CH}_3\text{O})_2\text{C}_6\text{H}_4$	
1,3-Diphenylisobenzofuran	$(\text{C}_6\text{H}_5)_2\text{C}_6\text{H}_2\text{OC}_6\text{H}_4$	
1,3,5-Benzenetricarboxylic acid	$\text{C}_6\text{H}_3(\text{CO}_2\text{H})_3$	
1,3,5-Trimethylbenzene	$(\text{CH}_3)_3\text{C}_6\text{H}_3$	
1,4-Dimethoxybenzene	$(\text{CH}_3\text{O})_2\text{C}_6\text{H}_4$	
1,4-Dinitrobenzene	$(\text{NO}_2)\text{C}_6\text{H}_4$	
1,4-Diphenyl-1,3-butadiene	$(\text{C}_6\text{H}_5)_2\text{C}_4\text{H}_4$	659
1,4-Naphthoquinone	$\text{C}_{10}\text{H}_6\text{O}_2$	
1,4-Pentanediole	$\text{CH}_3\text{CH(OH)(CH}_2)_3\text{OH}$	
1,10-Dichlorodecane	$\text{Cl(CH}_2)_{10}\text{Cl}$	199
1-Benzylnicotinamide	$(\text{C}_6\text{H}_5)\text{CH}_2(\text{C}_5\text{H}_3\text{N})\text{C(O)NH}_2$	
1-Bromodecane	$\text{BrC}_{10}\text{H}_{21}$	
1-Bromododecane	$\text{BrC}_{12}\text{H}_{25}$	
1-Butanol	$\text{CH}_3(\text{CH}_2)_3\text{OH}$	52g
1-Butylamine	$n\text{-C}_4\text{H}_7\text{NH}_2$	52g
1-Decene	$\text{CH}_2\text{CHC}_8\text{H}_{17}$	
1-Dodecanol	$\text{CH}_3(\text{CH}_2)_{11}\text{OH}$	
1-Hexene	$\text{C}_6\text{H}_{12}$	





**Table 2. Other Organic Compounds Treated by a Photocatalytic Process**

Substance	Formula	Reference
1-(Methoxyphenyl)-2-propanol	$(\text{CH}_3\text{OC}_6\text{H}_4)(\text{CH}_3)\text{CHOH}$	
1-Phenylethanol	$\text{CH}_3\text{CH}(\text{C}_6\text{H}_5)\text{OH}$	
1-Propanol	n-C <sub>3</sub> H <sub>7</sub> OH	52g
1-Nitronaphthalene	C <sub>10</sub> H <sub>7</sub> NO <sub>2</sub>	
2,2-Dichloropropionic acid	$\text{CH}_3\text{CCl}_2\text{CO}_2\text{H}$	112,113
2,2,6,6-Tetramethylpiperidone		1006
2,3-Dichloropyridine	$\text{Cl}_2\text{C}_5\text{H}_3\text{N}$	
2,3-, 2,4- or 3,4-Difluorophenol	$\text{F}_2\text{C}_6\text{H}_3\text{OH}$	
Tris-(2,4-dichlorophenoxy)ethyl-phosphite	$\text{C}_2\text{H}_5\text{P}[\text{OC}_6\text{H}_3\text{Cl}_2]_3$	
2,6-Dichlorophenol	$\text{C}_6\text{H}_3\text{Cl}_2\text{OH}$	
2,6-Di-tert-butylphenol		140,141
2,6-Di-tert-butyl-4-methylphenol		140,1006
2,6-Dimethylphenol		140,528
2,7-Dichlorodibenzo-p-dioxin	$\text{Cl}_2\text{C}_{12}\text{H}_6\text{O}_2$	
2-, 3-, or 4-Chlorobenzoic acid	$\text{ClC}_6\text{H}_4\text{CO}_2\text{H}$	181,183,184
2-, 4, or 6-chloroquinoline	$\text{C}_9\text{H}_7\text{NCl}$	97
2-, 3-, or 4-Fluorophenol	$\text{FC}_6\text{H}_4\text{OH}$	
2-,3-, or 4-Nitrotoluene	$\text{NO}_2\text{C}_6\text{H}_4\text{CH}_3$	
2,3-Benzofuran	$\text{C}_8\text{H}_6\text{O}$	
2,3- and 2,5-Dichlorophenol	$\text{Cl}_2\text{C}_6\text{H}_3\text{OH}$	
2,3-Dihydrobenzofuran	$\text{C}_8\text{H}_8\text{O}$	
2,3-Dimethyl-1,3-butadiene	$\text{CH}_2\text{C}(\text{CH}_3)\text{C}(\text{CH}_3)\text{CH}_2$	659
2,3,5-Trichlorophenol	$\text{Cl}_3\text{C}_6\text{H}_2\text{OH}$	
2,3,6-Trichlorobenzoic acid	$\text{Cl}_3\text{C}_6\text{H}_2\text{CO}_2\text{H}$	708
2,4-Dihydroxybenzoic acid	$(\text{HO})_2\text{C}_6\text{H}_3\text{CO}_2\text{H}$	684
2,4-Hexadienes		659
2,4-Dimethoxybenzene	$(\text{CH}_3\text{O})_2\text{C}_6\text{H}_4$	
2,4-xylindine	$\text{H}_2\text{NC}_6\text{H}_3(\text{CH}_3)_2$	
2,5-Dimethyl-2,4-hexadiene		659
2,5-Dinitrophenol	$(\text{NO}_2)_2\text{C}_6\text{H}_3\text{OH}$	
2,6-Dichloroindophenol	$\text{C}_8\text{H}_2\text{N}(\text{OH})\text{Cl}_2$	54
2,5-Furandimethanol	$\text{C}_4\text{H}_2\text{O}(\text{CH}_2\text{OH})_2$	
2,4,6-Trichlorophenyl oxalate	$(\text{Cl}_3\text{C}_6\text{H}_2)\text{C}_2\text{O}_4$	
2,4,6-Trinitrobenzoic acid	$(\text{NO}_2)_3\text{C}_6\text{H}_2\text{CO}_2\text{H}$	
2-Amino-5-diethylaminotoluene	$(\text{NH}_2)[(\text{C}_2\text{H}_5)_2\text{N}]\text{C}_6\text{H}_3\text{CH}_3$	
bis-(2-Dipyridyl)disulfide		847,848,849
2-Chloroaniline	$\text{ClC}_6\text{H}_4\text{NH}_2$	
2-Chlorobenzaldehyde	$\text{ClC}_6\text{H}_4\text{C}(\text{O})\text{H}$	
2-Chlorobiphenyl	$\text{ClC}_6\text{H}_4\text{C}_6\text{H}_5$	191,947, 948, 949,950
2-Chlorodibenzo-p-dioxin	$\text{ClC}_{12}\text{H}_7\text{O}_2$	
2-Chloroethylethylsulfide	$(\text{ClC}_2\text{H}_4)\text{C}_2\text{H}_5\text{S}$	
2-Chlorophenol	$\text{ClC}_6\text{H}_4\text{OH}$	710

**Table 2. Other Organic Compounds Treated by a Photocatalytic Process**

Substance	Formula	Reference
2-Chloroethylmethylsulfide	$(\text{ClC}_2\text{H}_4)\text{CH}_3\text{S}$	
2-Coumaranone	$\text{C}_8\text{H}_6\text{O}_2$	
2-Furoic Acid	$(\text{CH}_2)_3\text{CHOCO}_2\text{H}$	
2-Hexene	$\text{C}_6\text{H}_{12}$	
2 or 3 or 4-Halobenzylalcohols	$\text{HOCH}_2\text{C}_6\text{H}_4\text{X}$ (X=F, Cl. Or Br)	969
2 or 3 or 4-Hydroxyacetophenone	$\text{HOC}_6\text{H}_4\text{C}(\text{O})\text{CH}_3$	995
2-Hydroxypyridine	$\text{HOC}_5\text{H}_4\text{N}$	
2-Hydroxytetrahydropyran	$\text{HOC}_5\text{H}_9\text{O}$	
2-Methylbenzamidazole	$\text{C}_6\text{H}_4\text{N}_2\text{HCCH}_3$	
2-Methylbenzoic acid	$\text{CH}_3\text{C}_6\text{H}_4\text{CO}_2\text{H}$	934
2-Methylisoborneol	$\text{C}_{11}\text{H}_{20}\text{OH}$	
2-Methylpropionic acid	$(\text{CH}_3)_2\text{CH}_2\text{CO}_2\text{H}$	
2-Methyl-1,4-hydroquinone	$\text{CH}_3\text{C}_6\text{H}_3(\text{OH})_2$	
2-Methyl-2-nitropropane	$(\text{CH}_3)_2\text{CHNO}_2$	
2-Naphthol	$\text{C}_{10}\text{H}_7\text{OH}$	
2-Nitroaniline	$\text{O}_2\text{NC}_6\text{H}_4\text{NH}_2$	
2-Tolualdehyde	$\text{CH}_3\text{C}_6\text{H}_4\text{CHO}$	
2,2'-Dihydroxybiphenyl	$\text{C}_{12}\text{H}_8(\text{OH})_2$	
3,3,3-Trifluoropropene	$\text{CH}_2\text{CHCF}_3$	
3,4-Dihydroxybenzoic acid		853
3,3'-Dichlorobiphenyl	$(\text{ClC}_6\text{H}_4)_2$	
3,4,5-Trichlorophenol	$\text{Cl}_3\text{C}_6\text{H}_2\text{OH}$	
3,4-Dichloroaniline	$\text{Cl}_2\text{C}_6\text{H}_3\text{NH}_2$	
3,4-Dichlorophenol	$3,4\text{-Cl}_2\text{C}_6\text{H}_3\text{OH}$	
3,5-Dichlorophenol	$3,5\text{-Cl}_2\text{C}_6\text{H}_3\text{OH}$	
3,5-Di-tert-butylphenol		140,141
3,5-Di-methylphenol		140
3-Aminoanisole	$\text{CH}_3\text{OC}_6\text{H}_4\text{NH}_2$	
3-Bromoquinoline	$\text{C}_9\text{H}_7\text{NBr}$	97
3-Chloroaniline	$\text{CH}_3\text{OC}_6\text{H}_4\text{Cl}$	
3-Chloroanisole	$\text{ClC}_6\text{H}_4\text{NH}_2$	
3-Chlorobenzaldehyde	$\text{ClC}_6\text{H}_4\text{C}(\text{O})\text{H}$	
3-Chlorophenol	$m\text{-ClC}_6\text{H}_4\text{OH}$	188
3-Chlorosalicylic acid	$\text{C}_7\text{H}_5\text{ClO}_3$	
3-Chlorotoluene	$\text{CH}_3\text{C}_6\text{H}_4\text{Cl}$	
3-Fluoroanisole	$\text{CH}_3\text{OC}_6\text{H}_4\text{F}$	
3-Fluorotoluene	$\text{CH}_3\text{C}_6\text{H}_4\text{F}$	
3-Hydroxyanisole	$\text{CH}_3\text{OC}_6\text{H}_4\text{OH}$	
3-Methoxybenzylalcohol	$\text{CH}_3\text{C}_6\text{H}_5\text{CH}_2\text{OH}$	166
3-Methyl-2-oxobutanoic acid	$(\text{CH}_3)\text{CHC}(\text{O})\text{CO}_2\text{H}$	
3-Nitroanisole	$\text{CH}_3\text{OC}_6\text{H}_4\text{NO}_2$	
3-Nitrophenol	$\text{O}_2\text{NC}_6\text{H}_4\text{OH}$	275
3-Nitrotoluene	$\text{CH}_3\text{C}_6\text{H}_4\text{NO}_2$	



Table 2. Other Organic Compounds Treated by a Photocatalytic Process

Substance	Formula	Reference
3-Octanol	$\text{CH}_3\text{CH}_2\text{CH}(\text{OH})(\text{CH}_2)_4\text{CH}_3$	
3-Octanone	$\text{CH}_3\text{CH}_2\text{C}(\text{O})(\text{CH}_2)_4\text{CH}_3$	
4,6-Dichlororesorcinol		853
4-Acetobenzaldehyde	$\text{CH}_3\text{C}(\text{O})\text{C}_6\text{H}_4\text{CHO}$	
4-Aminoanisole	$\text{CH}_3\text{OC}_6\text{H}_4\text{NH}_2$	
4-Aminophenylarsonic acid		534
4-Bromophenol	$\text{BrC}_6\text{H}_4\text{OH}$	
4-t-Butyltoluene	$p\text{-}(\text{t-C}_4\text{H}_9)\text{C}_6\text{H}_4\text{CH}_3$	
4-Chloroanisole	$\text{CH}_3\text{OC}_6\text{H}_4\text{Cl}$	
4-Chlorobenzaldehyde	$\text{ClC}_6\text{H}_4\text{C}(\text{O})\text{H}$	
4-Chlorobenzenesulfonamide	$\text{ClC}_6\text{H}_4\text{SO}_2\text{NH}_2$	569
4-Chlorocatachol	$\text{ClC}_6\text{H}_3(\text{OH})_2$	493
4-Chloro-2-methylphenoxyacetic acid		1100
4-Chloro-3-methylnitrobenzene	$\text{Cl}(\text{CH}_3)\text{C}_6\text{H}_3\text{NO}_2$	285
4-Chloro-3-methylphenol	$\text{Cl}(\text{CH}_3)\text{C}_6\text{H}_3\text{OH}$	710
4-Chloro-3-nitro-benzotrifluoride	$\text{C}_6\text{HCl}(\text{NO}_2)\text{F}_3$	
4-Chlorophenol	$\text{ClC}_6\text{H}_4\text{OH}$	3, 104, 152, 189, 201, 223, 231, 282, 285, 308, 342, 400, 401, 424, 457, 460, 493, 494, 554, 578, 579, 585, 586, 732, 733, 886, 887, 1042, 1097, 1098
4-Chlorophenoxyacetic acid	$\text{ClC}_6\text{H}_4\text{CH}_2\text{CO}_2\text{H}$	714
4-Chlorophenylisocyanate	$\text{ClC}_6\text{H}_4\text{NCO}$	
4-Chlorotoluene	$\text{CH}_3\text{C}_6\text{H}_4\text{Cl}$	
4-Ethylaniline	$\text{NH}_2\text{C}_6\text{H}_4\text{C}_2\text{H}_5$	36
4-Fluoroanisole	$\text{CH}_3\text{OC}_6\text{H}_4\text{F}$	
4-Fluorophenol	$\text{FC}_6\text{H}_4\text{OH}$	
4-Fluorotoluene	$\text{CH}_3\text{C}_6\text{H}_4\text{F}$	
4-Hydroxyanisole	$\text{CH}_3\text{OC}_6\text{H}_4\text{OH}$	
4-Hydroxyacetophenone	$\text{HOC}_6\text{H}_4\text{C}(\text{O})\text{CH}_3$	
4-Hydroxyazobenzene	$\text{C}_6\text{H}_5\text{NNC}_6\text{H}_4\text{OH}$	268
4-Hydroxybenzyl Alcohol	$p\text{-HO}(\text{C}_6\text{H}_4)\text{CH}_2\text{OH}$	166
4-Hydroxybiphenyl	$\text{C}_{12}\text{H}_9\text{OH}$	
4-Iodophenol	$\text{IC}_6\text{H}_4\text{OH}$	
4-Methoxybenzyl alcohol	$\text{CH}_3\text{OC}_6\text{H}_4\text{CH}_2\text{OH}$	
4-Methoxybenzyl(methyl) ether	$\text{CH}_3\text{OC}_6\text{H}_4\text{CH}_2\text{OCH}_3$	
4-Methoxybenzyl(3-phenylpropyl)- ether	$\text{CH}_3\text{OC}_6\text{H}_4\text{CH}_2\text{O}(\text{CH}_2)_3\text{C}_6\text{H}_5$	
4-Methoxybenzyl(t-buetyl) ether	$\text{CH}_3\text{OC}_6\text{H}_4\text{CH}_2\text{OC}(\text{CH}_3)_3$	
4-Methoxybenzyl(phenyl)sulfide	$\text{CH}_3\text{OC}_6\text{H}_4\text{CH}_2\text{SC}_6\text{H}_5$	
4-Methoxyphenol	$\text{CH}_3\text{C}_6\text{H}_4\text{OH}$	554
4-Nitroaniline	$\text{NO}_2\text{C}_6\text{H}_4\text{NH}_2$	285
4-Nitroanisole	$\text{CH}_3\text{OC}_6\text{H}_4\text{NO}_2$	

**Table 2. Other Organic Compounds Treated by a Photocatalytic Process**

Substance	Formula	Reference
4-Nitrobenzaldehyde	$\text{NO}_2\text{C}_6\text{H}_4\text{CHO}$	
4-Nitrobenzamide	$\text{NO}_2\text{C}_6\text{H}_4\text{CONH}_2$	
4-Nitrobenzenesulfanamide	$\text{NO}_2\text{C}_6\text{H}_4\text{SO}_2\text{NH}_2$	
4-Nitrobenzoic acid	$\text{O}_2\text{NC}_6\text{H}_4\text{CO}_2\text{H}$	714
4-Nitrocatechol	$(\text{NO}_2)\text{C}_6\text{H}_3(\text{OH})_2$	
4-Chlororesorcinol		853
4-Nitromethylbenzenesulfonate	$\text{NO}_2\text{C}_6\text{H}_4\text{SO}_3\text{CH}_3$	
4-Nitromethylbenzoate	$\text{NO}_2\text{C}_6\text{H}_4\text{CO}_2\text{CH}_3$	
4-Nitrophenylethylphosphinate	$(\text{NO}_2)\text{C}_6\text{H}_4(\text{C}_2\text{H}_5)\text{PO}_2$	
4-Nitrophenylisopropylphosphinate	$(\text{NO}_2\text{C}_6\text{H}_5)(\text{C}_3\text{H}_7)\text{HPO}_3$	
4-Nitrophenyldiethylphosphate	$(\text{NO}_2\text{C}_6\text{H}_5)(\text{C}_2\text{H}_5)_2\text{PO}_4$	
4-Nitrosoimidazole		690
4-Nitrosophenol	$\text{ONC}_6\text{H}_4\text{OH}$	
4-Nitrosopyrazole		690
4-Nitrotoluene	$\text{CH}_3\text{C}_6\text{H}_4\text{NO}_2$	
4-Nonylphenol		326
4-Nonylphenolpolyethoxylate		326
4-Phenylbutylamine	$\text{C}_6\text{H}_5(\text{CH}_2)_4\text{NH}_2$	
4-Picoline	$\text{CH}_3\text{C}_5\text{H}_4\text{N}$	
4-tert-butylphenol	$(\text{CH}_3)_3\text{CC}_6\text{H}_4\text{OH}$	140
4-tert-butylpyridine	$(\text{CH}_3)_3\text{CC}_5\text{H}_4\text{N}$	638
4-(2-Pridinylazo)resorcinol		146
4-Thiophenyl-1-butanol	$\text{C}_6\text{H}_5\text{S}(\text{CH}_2)_4\text{OH}$	
4-Trifluoromethylphenol	$\text{CF}_3\text{C}_6\text{H}_4\text{OH}$	
4,4'-Dihydroxybiphenyl	$\text{C}_{12}\text{H}_8(\text{OH})_2$	
5-Bromouracil	$\text{BrC}_4\text{H}(\text{NH})_2(\text{O})_2$	
5-Chlorouracil	$\text{ClC}_4\text{H}(\text{NH})_2(\text{O})_2$	
5-Fluorouracil	$\text{FC}_4\text{H}(\text{NH})_2(\text{O})_2$	
5-Hydroxypentanoic acid	$\text{HO}(\text{CH}_2)_4\text{CO}_2\text{H}$	
6-Chlorovanillin		1045
6-Methoxytetralin	$\text{CH}_3\text{OC}_8\text{H}_5\text{O}$	
5-Methylresorcinol	$\text{CH}_3\text{C}_6\text{H}_5\text{O}_2$	
6-Methyluracil	$\text{CH}_3\text{C}_4\text{H}(\text{NH})_2(\text{O})_2$	169,170
9,10-Anthraquinone	$\text{C}_{14}\text{H}_8\text{O}_2$	95
9-Acetylanthracene	$\text{C}_{14}\text{H}_9\text{C}(\text{O})\text{CH}_3$	95
12-Nitrododecanoic acid	$\text{NO}_2\text{C}_{11}\text{H}_{22}\text{CO}_2\text{H}$	
12-phenyldodecanesulfonate, sodium salt	$\text{C}_6\text{H}_5(\text{CH}_2)_{12}\text{SO}_3\text{H}$	
17-Oestradiol		142
Acenaphthene	$\text{C}_{10}\text{H}_{16}(\text{CH}_2)_2$	
Acetic Acid or acetate ion	$\text{CH}_3\text{CO}_2\text{H}$	192,306,435,436,511,558g, 612g,613g,614g,643,790, 904
Acetone semicarbozone		415



Table 2. Other Organic Compounds Treated by a Photocatalytic Process

Substance	Formula	Reference
Acetophenone	$\text{CH}_3\text{COC}_6\text{H}_5$	
Acetylene	$\text{C}_2\text{H}_2$	
Acid Blue 9		1035g
Acid Blue 40		
Acid Blue 80		707
Acid chrome blue K		1037
Acid fuchsin		281
Acid orange 7	$\text{Na}_2\text{O}_3\text{SC}_6\text{H}_4\text{N}_2\text{C}_{10}\text{H}_6\text{OH}$	700
Acid rosaniline		1037
Acridine orange		108,109
Acrinathrin		543
Active Red X-3B		792,793,794, 795,796,797, 798,799
Adenine		324
Adipic acid	$\text{C}_5\text{H}_{11}\text{CO}_2\text{H}$	
Aldicarb	$\text{CH}_3\text{SC}(\text{CH}_3)_2\text{CHN}(\text{O})\text{C}(\text{O})\text{NHCH}_3$	
L-Alanine	$\text{CH}_3\text{CH}(\text{NH}_2)\text{CO}_2\text{H}$	325
Alizarin		62
Alizarin Red S Biological Stain		504,506,507
p-Alkylphenol (various)	$\text{R}(\text{C}_6\text{H}_4)\text{OH}$	
Allyl alcohol	$\text{C}_3\text{H}_5\text{OH}$	
Alochlor		
Amaranth		204,205
Ametryn		
Aminophenol, 2, 3, or 4	$\text{NH}_2\text{C}_6\text{H}_4\text{OH}$	554
Anatoxin-a		730
o-Anisidine	$\text{CH}_3\text{OC}_6\text{H}_4\text{NH}_2$	
Anthraquinone-2-sulfonic acid	$\text{HO}_3\text{SC}_{14}\text{H}_7\text{O}_2$	
AOX or Haloform Precursors		
L-Arginine	$\text{H}_2\text{NCHNH}(\text{CH}_2)_3\text{CH}(\text{NH}_2)\text{CO}_2\text{H}$	
L-Ascorbic acid		456
Aspartame	$\text{HO}_2\text{CCH}_2\text{CH}(\text{NH}_2)\text{C}(\text{O})\text{NHCH}-$ $(\text{C}_7\text{H}_7)(\text{CO}_2\text{CH}_3)$	
L-Aspartic acid	$\text{HO}_2\text{CCH}_2\text{CH}(\text{NH}_2)\text{CO}_2\text{H}$	
Asulam		
Auramine		204,205
Azinphos methyl	$\text{C}_{10}\text{H}_{12}\text{N}_3\text{O}_3\text{PS}_2$	
Azobenzenes (various)	$\text{XC}_6\text{H}_4\text{NNC}_6\text{H}_4\text{X}$	269,478
Azobisformamidoacetic acid		
Azodrin		
Bacteria/Algae/Virus/Cancer Cells/		28,58,133,164,176,194,

**Table 2. Other Organic Compounds Treated by a Photocatalytic Process**

Substance	Formula	Reference
Macrophages/Skin Fibroblasts/Fungi/Pollen		272g,322,338g,341,347g, 369,412,446,449, 459,465, 473,512,549,567,574,626, 630,632,657,664,677,688, 745,746,766,806,835,907, 928,971,1022,1140
Basagran		
Benthiocarb		
Benzaldehyde	$C_6H_5C(O)H$	63g,555g,556g
Benzofuran	$C_8H_6O$	
Benzophenone	$(C_6H_5)_2CO$	
Benzoquinone	$C_6H_4O_2$	479,811
Benzyl dodecyl dimethyl ammonium chloride	$(C_6H_5CH_2)(C_{12}H_{25})(CH_3)_2N,Cl$	
Benzyl ethers	$C_6H_5CH_2O-R$ $R=CH_3, n-C_6H_{13}, t-C_4H_9,$ $(CH_2)_3C_6H_5, CH_2C_6H_5$	
N-Benzylidene aniline (para substituted)	$p-R-C_6H_4CHNC_6H_5$ ( $R=H, OCH_3,$ $CH_3, Cl, \text{ or } Br$ )	
Benzyl phenylacetate	$C_6H_5CH_2CO_2CH_2C_6H_5$	149
Benzyl(phenyl)sulfide	$C_6H_5CH_2SC_6H_5$	
Benzyl tetradecyl dimethyl ammonium chloride	$(C_6H_5CH_2)(C_{14}H_{27})(CH_3)_2N,Cl$	
Biomass		
Bipthalate	$(C_6H_4)(CO_2H)CO_2(-1)$	
Bisphenol A		653
Brilliant green		204
Bromacil		216
Bromobenzene	$BrC_6H_5$	
Bromothymol Blue		
Bromoxynil		886,887
Butane	$C_4H_{10}$	
Butanoic acid	$C_3H_7CO_2H$	52g
But-1-ene	$CH_2CHCH_2CH_3$	88g,89g
But-2-ene	$CH_3CHCHCH_3$	348g
Butylacrylate	$C_4H_9O_2CCHCH_2$	
t-Butylazine		
n-Butyltin chloride	$C_4H_9SnCl_3$	
But-1-yne	$CHCCH_2CH_3$	
Carbamate pesticides		873
Carbetamide		
Carbofuran		458, 464



Table 2. Other Organic Compounds Treated by a Photocatalytic Process

Substance	Formula	Reference
Carbon dioxide (reduction)	CO <sub>2</sub>	11g, 13, 26, 144, 353, 398, 399, 717, 781, 825, 998, 999, 1009, 1014, 1053
Carbon monoxide	CO	195g, 196g, 402g, 698g, 920g 1107g
Carbon tetrabromide	CBr <sub>4</sub>	82
Catalase		
Catechol	C <sub>6</sub> H <sub>4</sub> (OH) <sub>2</sub>	
Cationic blue X-GRL		329
C12-Betaine	(C <sub>12</sub> H <sub>25</sub> )(CH <sub>3</sub> ) <sub>2</sub> NCO <sub>2</sub>	
C12-Amidobetaine		
Cetyldimethylbenzylammonium chloride	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>15</sub> (CH <sub>3</sub> ) <sub>2</sub> -(C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> )N, Cl	
Cetylpyridinium chloride or bromide	N-[CH <sub>3</sub> (CH <sub>2</sub> ) <sub>15</sub> ](C <sub>5</sub> H <sub>5</sub> N), Cl (or Br)	846
Cetyltrimethylammonium bromide	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>15</sub> (CH <sub>3</sub> ) <sub>3</sub> N, Cl	
Chloroacetaldehyde	CH <sub>2</sub> ClC(O)H	
Chlorobenzoic acids, o-, m-, or p-	Cl(C <sub>6</sub> H <sub>4</sub> )CO <sub>2</sub> H	
Chlorofluorocarbons, various		
Chloral hydrate	Cl <sub>3</sub> CO(OH) <sub>2</sub>	
Chloranil, o- and p-	C <sub>6</sub> Cl <sub>4</sub> O <sub>2</sub>	
o-Chlorobiphenyl	C <sub>12</sub> H <sub>9</sub> Cl	838
Chloroethylammonium chloride	ClH <sub>3</sub> N, Cl	
Chlorpyrifos		
Chlorsulfuron		569
Chrome black T		1037
Ciba orange RI		
Cinnamyl alcohol	C <sub>6</sub> H <sub>4</sub> C <sub>2</sub> H <sub>2</sub> OH	
Citric acid	HO <sub>2</sub> CCH <sub>2</sub> C(OH)(CO <sub>2</sub> H)CH <sub>2</sub> CO <sub>2</sub> H	159, 571
Coal or Carbon		
Color and/or COD (in wastewater)		
Congo red	C <sub>32</sub> H <sub>22</sub> O <sub>6</sub> N <sub>6</sub> S <sub>2</sub> Na <sub>2</sub>	713
Cresol violet	C <sub>16</sub> H <sub>8</sub> NO(NH <sub>2</sub> ), Cl	
Creosote phenolics		
Crystal violet		841
p-Coumaric acid	HOC <sub>6</sub> H <sub>4</sub> CHCHCO <sub>2</sub> H	
Coumarin		361
Cyanamide	NCNH <sub>2</sub>	
Cyanuric acid	C <sub>3</sub> N <sub>3</sub> (OH) <sub>3</sub>	885
Cyclododecanol	C <sub>12</sub> H <sub>23</sub> OH	
Cyclohexanedicarboxylic acids	C <sub>6</sub> H <sub>10</sub> (CO <sub>2</sub> H) <sub>2</sub>	
Cyclohexanol	C <sub>6</sub> H <sub>11</sub> OH	
Cyclohexene	C <sub>6</sub> H <sub>10</sub>	
Cyclohexene oxide	C <sub>6</sub> H <sub>10</sub> O	
Cyclooctatetraene	C <sub>8</sub> H <sub>8</sub>	
Cyclopentane	C <sub>5</sub> H <sub>10</sub>	

**Table 2. Other Organic Compounds Treated by a Photocatalytic Process**

Substance	Formula	Reference
Cyclophosphamide	OPONHC <sub>3</sub> H <sub>6</sub> [N(C <sub>2</sub> H <sub>4</sub> Cl) <sub>2</sub> ]	
t-Cinnamic acid	C <sub>6</sub> H <sub>5</sub> CHCHCO <sub>2</sub> H	714
D,L-Cysteine	HSCH <sub>2</sub> CH(NH <sub>2</sub> )CO <sub>2</sub> H	
Cytosine		170,324
DDT	(ClC <sub>6</sub> H <sub>4</sub> ) <sub>2</sub> CHCCl <sub>3</sub>	76,1095,1096
DNA and RNA		32, 324,992
Decalin	C <sub>10</sub> H <sub>18</sub>	
Decamethyltetrasiloxane	(CH <sub>3</sub> ) <sub>10</sub> Si <sub>4</sub> O <sub>3</sub>	
Decane	C <sub>10</sub> H <sub>22</sub>	742
Decanoic acid	C <sub>9</sub> H <sub>19</sub> CO <sub>2</sub> H	
Decanol	HOC <sub>10</sub> H <sub>21</sub>	
Desipramine	(C <sub>6</sub> H <sub>4</sub> ) <sub>2</sub> (CH <sub>2</sub> ) <sub>2</sub> N(CH <sub>2</sub> ) <sub>3</sub> NHCH <sub>3</sub>	
Diazinon	[(CH <sub>3</sub> ) <sub>2</sub> CHC <sub>4</sub> N <sub>2</sub> H(CH <sub>3</sub> )O]- PS(OC <sub>2</sub> H <sub>5</sub> ) <sub>2</sub>	
Dibenzothiophene	C <sub>12</sub> H <sub>8</sub> S	
Dibenzo-p-dioxines, various	X <sub>n</sub> C <sub>12</sub> H <sub>(8-n)</sub> O <sub>2</sub> (X=Cl or Br)	407
Dibenzylsulfone	[C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> ] <sub>2</sub> SO <sub>2</sub>	
Dibromomethane	CH <sub>2</sub> Br <sub>2</sub>	
Dichloroacetic acid	Cl <sub>2</sub> CHCO <sub>2</sub> H	41,173,217, 378
Diclofenthion		439
Dichloroacetyl Chloride	Cl <sub>2</sub> CHCOCl	211g
Diethylamine	(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub> NH	426,427
Diethyl ether	(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub> O	
Diethylmethylphosphanate		
Dihexadecylphosphate		
Dimethoate	(CH <sub>3</sub> O) <sub>2</sub> PSSCH <sub>2</sub> CONHCH <sub>3</sub>	
Dimethylacetamide	CH <sub>3</sub> C(O)N(CH <sub>3</sub> ) <sub>2</sub>	
Dimethylamine	(CH <sub>3</sub> ) <sub>2</sub> NH	
Dimethylaminoborane	(CH <sub>3</sub> ) <sub>2</sub> NHBH <sub>3</sub>	316
Dimethylarsinic acid		534
Dimethyl-2,2-dichlorovinyl phosphate		1024,1027,1071,1072,1073 1126,1127
Dimethylglyoxime	CH <sub>3</sub> N(H)CC(H)NCH <sub>3</sub>	414
Dimethylmethylphosphonate	(CH <sub>3</sub> O) <sub>2</sub> CH <sub>3</sub> PO	662g,741g
Dimethyl-2,2,2-trichloro-1-hydroxyethyl-phosphonate		
Dimethylphenols (Xylenols)	(CH <sub>3</sub> ) <sub>2</sub> C <sub>6</sub> H <sub>3</sub> OH	
Dimethylsulfide	(CH <sub>3</sub> ) <sub>2</sub> S	87g,649
Dimethyl-2,2-dichlorovinyl phosphate	(CH <sub>3</sub> ) <sub>2</sub> (Cl <sub>2</sub> CCH)PO <sub>4</sub>	
Diphenylacetylene	(C <sub>6</sub> H <sub>5</sub> ) <sub>2</sub> C <sub>2</sub>	
Diphenylamine	(C <sub>6</sub> H <sub>5</sub> ) <sub>2</sub> NH	
Diphenylmethane	(C <sub>6</sub> H <sub>5</sub> ) <sub>2</sub> CH <sub>2</sub>	
Diphenylsulfide	(C <sub>6</sub> H <sub>5</sub> ) <sub>2</sub> S	





Table 2. Other Organic Compounds Treated by a Photocatalytic Process

Substance	Formula	Reference
Diphenyltin chloride	$(C_6H_5)_2SnCl_2$	
Direct blue 1	$[(Na, O_3S)C_{16}H_6(NH_2)(OH)-(OCH_3)N_2]_2$	
Direct scarlet 4BS		124,381,1048,1141
Diquat		
Disinfection by-products		
Disperse blue 79		
Disperse red 74		
Diuron	$C_6H_3Cl_2NHC(O)N(CH_3)_2$	67,315
Dodecane	$C_{12}H_{26}$	117
Dodecyl sulfate, sodium salt	$(C_{12}H_{25})_2SO_4, Na$	468
Dodecylbenzenesulfonate, sodium salt	$(C_{12}H_{25})C_6H_4SO_3, Na$	83,264,666,987
Dodecyldecaoxyethylenephosphates	$(C_{12}H_{25})(CH_3)_3N, Br$	809
Dodecylpyridinium chloride	$(C_{12}H_{25})C_5H_5NH, Cl$	
Dodecyltrimethylammonium bromide		
Doxycycline		
Drimarene Yellow 3 GLI		
Dyes		29,107,164,216,249,269, 354,379,413,489,631,818, 832,834,876,881,929,935, 941,942,943,1002,1089, 1101,1103,1115,1117,1118 1135,1138,1141
Eosin		
Estradiol		652,653
Ethambutol		
Ethane	$C_2H_6$	
Ethanol	$C_2H_5OH$	52g,110,111,112,394g, 443g,610g,613g,614g, 633g,774,849,882g
Ethanol amine	$HOC_2H_4NH_2$	46,426,427
Ethylacetate	$CH_3CO_2C_2H_5$	
Ethyl amine	$C_2H_5NH_2$	426,427
Ethyl bromophos		439
Ethylenediaminetetraacetic acid and metal complexes	$(HO_2CCH_2)_4N_2C_2H_4$	66,111,137,138,139,159, 160,390,636,740,775,916, 1033,1034
Ethyl parathion		439
2-, 3-, or 4-Ethylphenol	$(C_2H_5)C_6H_4OH$	
Fast Orange GC Base		
Fenamiphos		312
Fenitrothion	$C_9H_{12}NO_5PS$	312
Fenobucarb		
Fluorescein	$C_{20}H_{12}O_5$	

**Table 2. Other Organic Compounds Treated by a Photocatalytic Process**

Substance	Formula	Reference
Flutriafol		646
Folicur		
Formamide	HC(O)NH <sub>2</sub>	977
Formic acid or formate ion	HCO <sub>2</sub> H	73,84,85,86,128,172,368, 496,571,581,582,611g,761 849
Fullerenes	C <sub>60</sub> , C <sub>70</sub> , and C <sub>84</sub>	
Fulvic acid		
Furfuryl alcohol		593
beta-D-Galactosidase		
Gasoline		462
Geosmin		487
Glucose	C <sub>6</sub> H <sub>11</sub> O <sub>6</sub>	456
L-Glutamic acid	HO <sub>2</sub> C(CH <sub>2</sub> ) <sub>2</sub> CH(NH <sub>2</sub> )CO <sub>2</sub> H	
L-Glutamine	H <sub>2</sub> NC(CH <sub>2</sub> ) <sub>2</sub> CH(NH <sub>2</sub> )CO <sub>2</sub> H	
Glycerol	C <sub>3</sub> H <sub>5</sub> (OH) <sub>3</sub>	590g
Glycerol trioleate		589g,590g
Glycolic acid	HOCH <sub>2</sub> CO <sub>2</sub> H	571
Glyoxylic acid	HO <sub>2</sub> CCO <sub>2</sub> H	197
Guanine		324
Halothane	CF <sub>3</sub> CBrCl	
HCFC or HFC		
Heparin		
Heptanal	C <sub>6</sub> H <sub>13</sub> CHO	
Hexafluorobenzene	C <sub>6</sub> F <sub>6</sub>	
Hexafluoropropene	CF <sub>2</sub> CFCF <sub>3</sub>	
HMX	(CH <sub>2</sub> ) <sub>4</sub> (NNO <sub>2</sub> ) <sub>4</sub>	
Hexanol	C <sub>6</sub> H <sub>13</sub> OH	
L-Histidine	C <sub>3</sub> N <sub>2</sub> H <sub>3</sub> CH <sub>2</sub> CH(NH <sub>2</sub> )CO <sub>2</sub> H	
Humic Acids		50,51,103,418,474,594,837 927
Hydroxybenzoic acid (various)	HOC <sub>6</sub> H <sub>4</sub> (OH)CO <sub>2</sub> H	
Hydroxycarboxylic acids, alpha	RCH(OH)CO <sub>2</sub> H	
Hydroxyethylcellulose		
Imidacloprid		224,886,887,1136
Imidazole	C <sub>3</sub> H <sub>4</sub> N <sub>2</sub>	
Indole	C <sub>8</sub> H <sub>6</sub> NH	
Iprobenfos		
Isobutane	C <sub>4</sub> H <sub>10</sub>	
Isobutanol	CH <sub>3</sub> CH(CH <sub>3</sub> )CH <sub>2</sub> OH	
Isobutene	C <sub>4</sub> H <sub>8</sub>	
Isobutyric Acid	CH <sub>3</sub> CH(CH <sub>3</sub> )CO <sub>2</sub> H	
L-iso-Lucine	C <sub>2</sub> H <sub>5</sub> CH(CH <sub>3</sub> )CH(NH <sub>2</sub> )CO <sub>2</sub> H	



Table 2. Other Organic Compounds Treated by a Photocatalytic Process

Substance	Formula	Reference
Isonicotinaldehyde	$C_5H_4NCHO$	
Isoprene	$CH_2C(CH_3)CHCH_2$	370g
Isoprothiolane		
Isosorbide dinitrate	$C_6O_2H_8(ONO_2)_2$	
Iso-octane	$(CH_3)_2CH(CH_2)_4CH_3$	
L-Lysine	$NH_2(CH_2)_4CH(NH_2)CO_2H$	
Lactic acid	$C_3H_6O_3$	
Landfill leachate		
Laurylsulfate, sodium salt	$C_{12}H_{25}SO_4, Na$	14,912
Levulinic acid	$CH_3C(O)CH_2CH_2CO_2H$	79
Lignin		531,872
Limonene	$C_9H_{16}$	
Linoleic acid	$C_{18}H_{31}CO_2H$	
L-Leucine	$(CH_3)_2CHCH_2CH(NH_2)CO_2H$	
Lufenuron		547
Luminol-CL		
Malachite green oxalate	$(C_6H_5)[C_6H_4N(CH_3)_2][C_6H_4N(CH_3)_2]C_2O_4 \cdot H_2C_2O_4$	
Maleic acid	$HO_2CCHCHCO_2H$	
Maleic anhydride	$O_2CCHCHCO_2$	42
Malic acid	$HO_2CCH_2CH(OH)CO_2H$	309
Malonaldehyde	$H(O)CCH_2C(O)H$	
Malonic acid	$CH_2(CO_2H)_2$	
Manitol	$HOCH_2[CH(OH)]_4CH_2OH$	
Mecoprop		895,897
Mercaptotetrazole	$HSN_4H$	
Mesitylene	$(CH_3)_3C_6H_3$	
Metalaxyl		896
Methamidophos		545
Methane	$CH_4$	120g, 121g, 122g, 270g
Methanethiol	$CH_3SH$	
L-Methionine	$CH_3S(CH_2)_2CH(NH_2)CO_2H$	
Methomyl		
N-Methylaniline	$C_6H_5NHCH_3$	
Methyl bromophos		439
Methylcyclohexane	$CH_3C_6H_{11}$	
Methyl-2-naphthoate	$C_{10}H_7CO_2CH_3$	
Methylnitrophos		
Methyl oleate		1006
Methyl orange	$Na_2O_3SC_6H_4N_2C_6H_4N(CH_3)_2$	148,205,329,330,785,944, 945,946,973,1064,1065, 1066,1067,1068,1070
Methyl parathion		439,757
Methyl perfluoroethyl ether	$CH_3OC_2F_5$	461g

**Table 2. Other Organic Compounds Treated by a Photocatalytic Process**

Substance	Formula	Reference
Methyl perfluoro-1-propyl ether	CH <sub>3</sub> OC <sub>3</sub> F <sub>7</sub>	461g
Methyl perfluoro-2-propyl ether	CH <sub>3</sub> OC <sub>3</sub> F <sub>7</sub>	461g
Methyl stearate	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>16</sub> CO <sub>2</sub> CH <sub>3</sub>	711g
Methylstyrene	C <sub>6</sub> H <sub>5</sub> (CH <sub>3</sub> )CCH <sub>2</sub>	
Methyl viologen	(CH <sub>3</sub> C <sub>5</sub> H <sub>4</sub> N) <sub>2</sub> .Cl <sub>2</sub>	557,635
Methyl violet		454,841
Methylene blue	(CH <sub>3</sub> ) <sub>2</sub> NC <sub>6</sub> H <sub>3</sub> NSC <sub>6</sub> H <sub>3</sub> N(CH <sub>3</sub> ) <sub>2</sub> .Cl	207,208,213,221,229,247, 409,475,481,482,483,536, 537,570,583,657,668,682, 777,778,800,814,815,841, 882g,993,1044
Methylvinylketone	CH <sub>3</sub> COC <sub>2</sub> H <sub>3</sub>	
Microcystin-LR or YR or YA		218,219,467,729,730,791,
Mixed waste		
Molasses		
Monocrotophos		118,1091,1139
Monuron	ClC <sub>6</sub> H <sub>4</sub> NHCON(CH <sub>3</sub> ) <sub>2</sub>	
Morpholine	C <sub>4</sub> H <sub>8</sub> ONH	
Myrcene	C <sub>10</sub> H <sub>16</sub>	
m-Phenoxytoluene	m-C <sub>6</sub> H <sub>5</sub> O-C <sub>6</sub> H <sub>4</sub> CH <sub>3</sub>	
N-Benzylidiphenylamine	(C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> )(C <sub>6</sub> H <sub>5</sub> ) <sub>2</sub> N	
N-Docanoyl-beta-alanine		
N-Dodecanoylglutamate		
N'-Dodecyl-N,N-dimethyl ammonium- acetate, sodium salt		
N'-Dodecylamidopropyl-N,N-dimethyl- ammonium acetate, sodium salt		
N-Dodecanoyl-N-(2-hydroxyethyl)amide	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>10</sub> C(O)NH(CH <sub>2</sub> ) <sub>2</sub> OH	
N-Dodecanoyl-N,N-bis(2-hydroxyethyl)- amide	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>10</sub> C(O)N[(CH <sub>2</sub> ) <sub>2</sub> OH] <sub>2</sub>	
N-Hydroxysuccinimide	C <sub>2</sub> H <sub>4</sub> (C(O)) <sub>2</sub> NOH	
N-Methylpyrrolidinone		230
N-Phenyl-1,4-phenylenediamine	C <sub>6</sub> H <sub>5</sub> NHC <sub>6</sub> H <sub>4</sub> NH <sub>2</sub>	
N,N,N',N'-Tetraethyloxonine		
alpha-Naphthaleneacetic acid	C <sub>10</sub> H <sub>7</sub> CH <sub>2</sub> CO <sub>2</sub> H	
Naphthol	C <sub>10</sub> H <sub>7</sub> OH	
Naphthol ASBS dye		716
Naphthol blue black	(C <sub>6</sub> H <sub>5</sub> N <sub>2</sub> )C <sub>12</sub> H <sub>2</sub> (OH)(NH <sub>2</sub> )- (SO <sub>3</sub> Na) <sub>2</sub>	258,821
Nicotinamide Coenzymes		
Nicotine	C <sub>5</sub> H <sub>4</sub> NC <sub>4</sub> H <sub>7</sub> NCH <sub>3</sub>	
Nile Blue A	C <sub>16</sub> NO(NH <sub>2</sub> )N(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub> .SO <sub>4</sub>	
Nitrocellulose		



Table 2. Other Organic Compounds Treated by a Photocatalytic Process

Substance	Formula	Reference
m-Nitrocinnamic acid		694
o-Nitrophenyl-beta-D-galactopyranoside	$C_{12}H_{15}NO_8$	
Nitropropane	$CH_3CH_2CH_2NO_2$	
Nitrosobenzene	$ONC_6H_5$	
p-Nitrosodimethylaniline	$ONC_6H_4N(CH_3)_2$	
p-Nitrotoluenesulfonic acid	$(CH_3)(NO_2)C_6H_3SO_3H$	
Nitrotoluene, various	$NO_2C_6H_4CH_3$	175
Nonylphenylethoxylate	$C_9H_{17}C_6H_4OC_2H_5$	
n-Nonylphenylpolyoxyethylene ethers	$C_9H_{17}C_6H_4O(C_2H_4O)_nH$	
Octadecane	$n-C_{18}H_{38}$	588g,589g,590g
Octadecanoic acid	$n-C_{17}H_{35}CO_2H$	589g,
n-Octanoic acid	$C_7H_{15}CO_2H$	
n-Octanol	$C_8H_{17}OH$	
Octanal	$C_7H_{15}CHO$	
Octaphenylcyclotetrasiloxane	$(C_6H_5)_8(SiO_2)_4$	
Oil/Petroleum		278,279,290,742,921,1129, 1130
Oleic acid	$CH_3(CH_2)_7CH=CH_2$	283g,514g,923g,925g
Oxalic acid or oxalate ion	$C_2O_4H_2$	7,48,81,135,159,428,441, 444,445,450,496,703
Orange I, II, III, or IV		47,456
Orange G		343
Oxamyl		544,886,887
PCB - polyhydroxy		
Paint waste		689
Palmitic (hexadecanoic) acid	$CH_3(CH_2)_{14}CO_2H$	734g,735g
Paraffin, liquid		590g
Paraoxone		83
Paraquat		604,915
Pendimethalin		
Pentachloroethane	$C_2HCl_5$	
Pentaethyleneglycol n-dodecyl ether	$(HO)(CH_2CH_2O)_5(C_{12}H_{23})$	
Pentafluorophenol	$C_6F_5OH$	
n-Pentyl amine	$n-C_5H_{11}NH_2$	
Permethrin		
Pesticides - unspecified		209,546,547,813,835,907, 908,1024,1119
Pirimiphos-methyl		312,313
beta-Phellandrene		
Phenacetylthioether	$C_6H_5CH_2SCH_2C(C_6H_5)CH_2$	
Phenosafranin	$C_6H_5N_2C_{12}H_4(NH_2)(CH_3)_2$	
Phenoxyacetic acid	$C_6H_5OCH_2CO_2H$	
Phenylacetic acid	$C_6H_5CH_2CO_2H$	
L-Phenylalanine	$C_6H_5CH_2CH(NH_2)CO_2H$	325

**Table 2. Other Organic Compounds Treated by a Photocatalytic Process**

Substance	Formula	Reference
Phenylarsonic acid		534
Phenylsulfinylacetic acid	$C_6H_5S(O)CH_2CO_2H$	
Phenylsulfonylacetic acid	$C_6H_5S(O)_2CH_2CO_2H$	
Phenylthioacetic acid	$C_6H_5SCH_2CO_2H$	
Phenyltrifluoromethyl ketone	$C_6H_5C(O)CF_3$	889
p-Phenylenediamine	$H_2NC_6H_4NH_2$	
Phenylhydroxylamine	$C_6H_5NHOH$	
Phenylmercaptotetrazole	$C_6H_5SN_4H$	
Phenyltetrazole	$C_6H_5N_4H$	
Phorate	$(C_2H_5O)P(S)SCH_2SC_2H_5$	280
Phthaldialdehyde	$C_6H_4(CHO)_2$	
Phthalan		
Phthalic acid	$C_6H_4(CO_2H)_2$	62,274
Phthalazinyldiazones		
Phthalocyanine		516g
Picoline	$CH_3C_5H_4N$	
Pinene (alpha or beta)	$C_{10}H_{16}$	
Piperidene	$C_5H_{10}NH$	
Pirimicarb		720
Polyacrylamide	$[CH_2CHC(O)NH_2]_n$	126
Polyethoxylene alkyl ethers	$R_2(OC_2H_4)_n$	590g,843,1145
Polyethylene	$(CH_2CH_2)_n$	
Poly(methylphenylsiloxane)	$[(C_6H_5)(CH_3)SiO]_n$	
Polypropylene	$[(CH_3)CHCH_2]_n$	
Polyvinylalcohol	$(C_2H_3OH)_n$	
Polyvinylchloride (PVC)	$(CH_2CHCl)_n$	265,596,1079g
Polyvinylpyrrolidone		323
Procion red		
Procymidone		
L-Proline	$C_4H_8NCO_2H$	
Prometon		
Prometryn		
Propane	$C_3H_8$	861g,877g
Propanil	$(3,4-Cl_2C_6H_3)NH(O)CC_2H_5$	547
Propamocarb		
Propazine		
Propionamide	$CH_3CH_2C(O)NH_2$	1051
Propionic acid	$C_2H_5CO_2H$	
Propyzamide		
Propylene	$C_3H_6$	
Propylene glycol	$CH_3CH(OH)CH_2OH$	
Propylene glycol dinitrate	$CH_3CH(NO_3)CH_2(NO_3)$	
Propylene sulfide	$C_3H_6S$	87g



Table 2. Other Organic Compounds Treated by a Photocatalytic Process

Substance	Formula	Reference
Propyne	CH <sub>3</sub> CCH	1013
Propyzamide		
Pyridine	C <sub>5</sub> H <sub>5</sub> N	440,441
Pyrimethanil		2,223
Pyrocatechol	o-C <sub>6</sub> H <sub>4</sub> (OH) <sub>2</sub>	
Pyrrole	C <sub>4</sub> H <sub>5</sub> N	
Pyrrole-2-carboxylic acid	C <sub>4</sub> H <sub>4</sub> (CO <sub>2</sub> H)N	441
Pyrrolidone		323
Quinoline acid yellow		
Reactive Blue 19		697
Reactive Blue 221		273
Reactive Blue 222		273
Reactive Dyes		229,273,329,453,644,645, 936,996,1109,1116
Reactive Red M5B		
Red Dye 79		
Red Dye 4BS		
Remazol Black B		30,273
Remazol Turquoise Blue G 133		30
Remazol Brilliant Blue R		273
Resorcinol		191,853
Rhodamine B	CH <sub>3</sub> OC(O)(C <sub>6</sub> H <sub>4</sub> )C <sub>13</sub> H <sub>6</sub> O(NH <sub>2</sub> ) <sub>2</sub>	306,529,530,696,712,937, 938,939,966,1081
Rhodamine 6G	C <sub>2</sub> H <sub>5</sub> OC(O)C <sub>6</sub> H <sub>4</sub> C <sub>13</sub> H <sub>4</sub> (CH <sub>3</sub> ) <sub>2</sub> - [N(C <sub>2</sub> H <sub>5</sub> )] <sub>2</sub> ,Cl	
Rhodamine 6ZH		
Rose Bengal	Na <sub>2</sub> O <sub>2</sub> CC <sub>6</sub> Cl <sub>4</sub> C <sub>13</sub> H <sub>2</sub> OI <sub>4</sub> O <sub>2</sub>	488
S-Dodecyl thioether carboxylates		
S-Ethyl-N,N-dipropyl thiocarbamate (EPTC)	(C <sub>2</sub> H <sub>5</sub> )SC(O)N(C <sub>3</sub> H <sub>7</sub> ) <sub>2</sub>	
S-Ethyl-N,N-diisopropylthiocarbamate (Butylate)	(C <sub>2</sub> H <sub>5</sub> )SC(O)N(i-C <sub>3</sub> H <sub>7</sub> ) <sub>2</sub>	
S-Ethyl-4-hexahydro-1-H-azepine-1- carbothionate (molinate)		
S-Propyl-N-cyclohexyl thiocarbamate (cycloate)	(C <sub>3</sub> H <sub>7</sub> )SC(O)NH(C <sub>6</sub> H <sub>11</sub> )	
S-Propyl-N,N-dipropyl thiocarbamate (vernolate)	(C <sub>3</sub> H <sub>7</sub> )SC(O)(NC <sub>3</sub> H <sub>7</sub> ) <sub>2</sub>	
Sabinine		
Saccharin		317
Salicylaldehyde	C <sub>7</sub> H <sub>6</sub> O <sub>2</sub>	
Salicylic acid	C <sub>7</sub> H <sub>6</sub> O <sub>3</sub>	62,143,714,894,1042,1094
L-Serine	HOCH <sub>2</sub> CH(NH <sub>2</sub> )CO <sub>2</sub> H	325

**Table 2. Other Organic Compounds Treated by a Photocatalytic Process**

Substance	Formula	Reference
Simazine	$(C_2H_5)Cl(NHC_2H_5)C_3N_3$	
Sirius yellow		205
Sodium anthracene-1-sulfonate		62
Sodium chloroacetate	$ClCH_2CO_2Na$	
Sodium dodecylbenzene sulfonate	$C_{12}H_{25}C_6H_4SO_3, Na$	409,850
Soluble dye 4BS		123
Special brilliant blue FFR		
Squalene		248g,393g
Stearic acid	$CH_3(CH_2)_{16}CO_2H$	588g,590g,721g,768g
Stilbene	$C_6H_5CH=CHC_6H_5$	
Succinic acid	$HO_2CCH_2CH_2CO_2H$	
Succinimide	$HNC(O)CH_2CH_2C(O)$	
Sucrose	$C_{12}H_{22}O_{11}$	
Sulfones	$RS(O)_2R'$	
Sulforhodamine B		505,508
Sulfosalicylic acid		509,510
Superoxide dismutase (SOD)		
Surfactants - unspecified		334,676
Tartaric acid	$HO_2CCH(OH)CH(OH)CO_2H$	
Terbutryne		
Terpinene	$C_{10}H_{16}$	
alpha-Terpineol	$C_{10}H_{18}O$	
Tetrabutylammonium phosphate	$[(n-C_4H_9)_4N]_4, PO_4$	
Tetrachloroaniline	$Cl_4C_6HNNH_2$	
Tetrachlorvinphos	$CHClCH(2,4,5-Cl_3C_6H_2)(CH_3)PO_4$	
Tetracycline		332,384,1080
Tetradecyldimethylbenzylammonium-chloride	$CH_3(CH_2)_{13}(CH_3)_2(C_6H_5CH_2)-NCl$	
Tetrafluoroethylene	$C_2F_4$	
Tetralin	$C_{10}H_{12}$	
Tetramethylenediamine	$NH_2(CH_2)_4NH_2$	
Tetranitromethane	$C(NO_2)_4$	
Meso-Tetraphenylporphyrin		397
Theophylline	$C_7H_8N_4O_2 \cdot H_2O$	
Thianthrene	$C_{13}H_8OS$	
Thioethers	$RSR'$	
Thiobencarb		
Thiolactic acid	$CH_3CH(SH)CO_2H$	
Thiophene	$C_5H_5S$	87g
Thiophenol	$C_6H_5SH$	
Thioxanthene	$C_{12}H_8S_2$	
Thioxanthone	$C_{13}H_8OS$	
Thifensulfuron Me		569





Table 2. Other Organic Compounds Treated by a Photocatalytic Process

Substance	Formula	Reference
Thiram		
Thymine	$C_5H_6N_2O_2$	169,170,324
Thionine	$C_{12}NS(NH_2)_2O_2CCH_3$	
L-Threonine	$CH_3CH(OH)CH(NH_2)CO_2H$	
p-Toluenesulfonic acid	$CH_3C_6H_4SO_3H$	
p-Toluidine	$CH_3C_6H_4NH_2$	
Tordon		315
Total Organic Carbon (TOC)		4,43,44,49,115,164,174, 176,177,178,247,328,334, 474,654,695,870,932
Triadimefon		720
s-Triazines		
Trichloroacetic acid	$Cl_3CCO_2H$	830
Trietazine		
Triethanolamine	$N(CH_2CH_2OH)_3$	336g,426,427
Trifluoroacetic acid	$CF_3CO_2H$	889
Trifluoroacetyl chloride	$CF_3C(O)Cl$	1099
Trihydrazinotriazine		
Trihydroxybenzene	$(HO)_3C_6H_3$	
Trimethylamine	$(CH_3)_3N$	745g
Trimethylammonium chloride	$(CH_3)_3NH,Cl$	
Trimethylene sulfide	$(CH_2)_3S$	87g
Trinitrophenol	$(NO_2)_3C_6H_2OH$	
Triphenylacetic acid	$(C_6H_5)_3CCO_2H$	
Triphenylbismuthine	$(C_6H_5)_3Bi$	
Triphenylphosphine	$(C_6H_5)_3P$	
Triphenylstibine	$(C_6H_5)_3Sb$	
L-Tryptophan	$C_8NH_6CH_2CH(NH)CO_2H$	
Tri-(p-Tolyl)arsine	$(CH_3C_6H_4)_3As$	
Triton X-100	$C_8H_{17}C_6H_4(OCH_2CH_2)_xOH$	
Umbelliferone	$C_9H_6O_3$	
Uracil	$HNC(O)NHC(O)CHCH$	169,170,375
Urea	$C(O)(NH_2)_2$	
L-Valine	$(CH_3)_2CHCH(NH_2)CO_2H$	
Vat Blue		
Vinclozolin		



**Table 3. Inorganic Substances Included in EPA Lists of Hazardous Substances and/or Treated by a Photocatalytic Process**

Substance/Element	Formula/Symbol	Reference
Actinides	Th,Pa,U,Np,Pu	
Aluminum (fume or dust)	Al	
Aluminum oxide	Al <sub>2</sub> O <sub>3</sub>	
Ammonia	NH <sub>3</sub>	745g,1131
Ammonium nitrate (soln)	NH <sub>4</sub> NO <sub>3</sub>	
Ammonium sulfate (soln)	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	
Antimony	Sb	
Arsenic	As	
Asbestos	Mg,Si	
Azide ion	N <sub>3</sub> <sup>(-)</sup>	
Barium	Ba	
Beryllium	Be	
Bismuth	Bi	
Boron	B	316
Bromate ion	BrO <sub>3</sub> <sup>(-1)</sup>	
Cadmium	Cd	128,160,318
Chlorine	Cl	
Chlorine dioxide	ClO <sub>2</sub>	
Chromium	Cr	66,116,143,231,232,233, 263,378,447,523,636,1102, 1112,1132
Cobalt	Co	
Copper	Cu	137,318,586,762,812,1033, 1034
Cyanide and Complexes	CN <sup>(-1)</sup> and M(CN) <sub>x</sub>	34,37,249,533,964
Cyanate ion	CNO <sup>(-1)</sup>	
Gold	Au	
Halide ion	X <sup>(1-)</sup> , X = F, Cl, Br, or I	360,442
Hydrazine and derivatives	H <sub>2</sub> NNH <sub>2</sub>	101,456, 922
Hydrogen sulfide	H <sub>2</sub> S	
Hydroxylamine	NH <sub>2</sub> OH	
Hypophosphorus acid	H <sub>2</sub> PO <sub>2</sub>	
Iridium	Ir	
Iron	Fe	
Lead	Pb	65,129,318,575,916
Manganese	Mn	233,314,409
Mercury	Hg	8,318,586
Molybdenum	Mo	
Molybdenum hexacarbonyl	Mo(CO) <sub>6</sub>	



**Table 3. Inorganic Substances Included in EPA Lists of Hazardous Substances and/or Treated by a Photocatalytic Process**

Substance/Element	Formula/Symbol	Reference
Nickel	Ni	316
Nitrates/nitrites	NO <sub>3</sub> (-1),NO <sub>2</sub> (-1)	51,187,262,496,608,715, 801,828,829,11-2
Nitrogen oxides	NO <sub>x</sub> , N <sub>2</sub> O	20g, 21g,23g,26g,71g, 246g,252g,253g,294g, 304g,356g,364g,369,395g, 407,499g,563g,603g,607g, 620g,621g, 623,629g,639g, 640g, 641g,642g,855g, 857g,858g,862g,863g,864g 865g,866g,867g,868g,869g 953g,989g,1012g,1106g
Nitrogen	N <sub>2</sub>	
Oxygen	O <sub>2</sub>	
Ozone	O <sub>3</sub>	
Palladium	Pd	1038
Phosphorus	P	
Platinum	Pt	
Radium	Ra	
Radon	Rn	
Rhodium	Rh	
Selenium	Se	761
Silicon	Si	
Silver	Ag	409,437,452,819,845,1038
Strontium	Sr	
Sulfate radical	SO <sub>4</sub> (1-)	
Sulfite	SO <sub>3</sub> (1-)	187
Sulfur	S	
Sulfur oxides	SO <sub>x</sub>	190g,780g,862g,865g
Sulfuric acid	H <sub>2</sub> SO <sub>4</sub>	
Thallium	Tl	
Thiocyanate	SCN(1-)	163
Thiosulfate	S <sub>2</sub> O <sub>3</sub> (2-)	456
Thorium	Th	
Tin	Sn	
Tritium	H,(T)	
Tungsten	W	
Uranium	U	111
Vanadium	V	
Zinc	Zn	128



## 4.0 Conclusions

The level of activity in this field remains high. The potential to develop new technology for environmental remediation is still a driving force for the R&D activity in some parts of the world; however, applications such as indoor air purification, disinfection and cell killing, and self-cleaning surfaces have moved more quickly to commercialization in Japan and to a much lesser extent in Europe and the United States. Clearly, many companies see potential markets for indoor air quality applications and self-cleaning surfaces. Products have been available in Japan for a number of years and are beginning to enter the market in the United States. Continued attention is being paid to detecting and identifying intermediates and by-products that can be formed during the photocatalytic process in aqueous and gas-phase systems. This is an important tool in developing an understanding of the chemical mechanisms of the processes and is necessary to ensure that potentially harmful substances are not left in the processed stream. Release of partial oxidation products is a major consideration for systems that treat indoor air. As systems are deployed in the field, it is increasingly important that the issues of catalyst lifetime and regeneration be addressed. Related to this is the need to identify those components of an air or water stream that can inhibit or kill catalyst activity. All these are important to the design of efficient and economical treatment systems.



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### 5.3 Address for Sending Corrections or Additions to the Bibliography

I constantly come across earlier references that have not turned up in literature searches or in the course of reading the literature. Please feel free to send me corrections or references to work appearing prior to mid-2001 that may have been left out of the list of references in this or the previous reports:

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