Precision Bombing, Widespread Harm
Two Case Studies of the Bombings of Industrial Facilities at Pancevo and Kragujevac During Operation Allied Force, Yugoslavia 1999

Sriram Gopal and Nicole Deller
Institute for Energy and Environmental Research

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Contributing Authors

Sriram Gopal, principal author and IEER's Staff Scientist, holds a bachelor's degree in Biochemistry and a second major in French from the University of Maryland (1998) as well as a master's degree in Marine, Estuarine, and Environmental Science, also from the University of Maryland, (2000) with an emphasis on the biodegradation of toxics. He is a co-author of IEER's report, *Setting Cleanup Standards to Protect Future Generations*.

S. Nicole Deller, J.D., co-author of Chapter 5 of this report, is an attorney with experience in commercial litigation and public international law, including advocacy of human rights and women's rights. As researcher and consultant to IEER and the Lawyer's Committee on Nuclear Policy, she was the principal editor and a contributing author of *Rule of Power or Rule of Law? An Assessment of U.S. Policies and Actions Regarding Security-Related Treaties*.

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Sriram Gopal
Nicole Deller
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Preface

This study was triggered by concerns over the health and environmental impacts of modern war. Our main goal in addressing this issue was to examine whether precision targeting is synonymous with precision damage. Is damage limited to the announced objective of the bombing? And if not, what are the environmental and legal implications from the indiscriminate destruction resulting from successful precision bombing strikes?

This limited research effort encountered significant unforeseen problems. Yugoslavia has been in political turmoil for most of the past decade and gaining access to hard data proved much more difficult than was initially anticipated. Additionally, the lack of access to information was not limited to Yugoslavia. A request was made by IEER to the U.S. Department of Defense under the Freedom of Information Act to get information on the targeting criteria used during Operation Allied Force. In response, we got 42 blank pages that were marked declassified, but were otherwise completely devoid of information. Even the names of the facilities for which information was requested were not on the pages. Our appeal to the Department of Defense was turned down. Furthermore, in 2002, the U.S. General Accounting Office, the investigative arm of the U.S. Congress, prepared an analysis of the 1999 bombing campaign in Yugoslavia that remains classified by the U.S. Department of Defense.

A trip to Yugoslavia by Sriram Gopal, the principal author of this report, and Joan McQueeney Mitric, our Serbian speaking consultant, yielded some useful information and invaluable insights from site visits to Pancevo and Kragujevac, but much of what we sought remains inaccessible. Despite these setbacks and the incomplete nature of the data presented here, this study is quite relevant and timely when set against current foreign policy military debates, most immediately about Iraq. We hope this study will serve as a vehicle to raise legal, health, and environmental issues that can be applied to other armed conflicts, especially in relation to the targeting and destruction of civilian industrial facilities.

Among the most pertinent points to consider are the use of precision weapons, targeting criteria, long-term environmental effects, and the need for and expense of post-conflict cleanup. Since Operation Allied Force ended in June 1999, precision weapons have been used in Afghanistan and are likely to be a major part of the military strategy in any proposed war with Iraq if it is carried out.[1] This study illustrates that the use of precision weapons often can have unintended and long-term damaging consequences. Furthermore, the chemical plants described in this report were most likely bombed because they fell into the category of "dual-use" facilities. The definition of dual-use is not clear and seems to expand or contract from conflict to conflict and target to target. Whatever definition is in play in a particular conflict/war has a direct effect on the choice of target sets and the bombing rationale of the attacking forces.[2]

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[1] Gilmore, 2002; Arkin, 2002.
[2] Rizer, 2001.

Finally, this report shows that the term "collateral damage" is also in need of sharp redefinition. The term is often used in the context of quantifiable damage, such as civilian deaths or the cost of replacing destroyed property. However, this report shows that the potentially long-term nature of environmental damage makes it very difficult to quantify and therefore difficult to integrate into an assessment of "collateral damage" currently in use by the military or the human rights community.

At this moment, the United States is considering a large-scale attack on Iraq. Since the end of the 1991 Gulf War, there has been considerable documentation of widespread and long-term damage to civilian health, especially in children, caused by successful precision bombing of water purification facilities during that conflict.[3] The legal, health, and environmental issues considered in this study should not be dismissed out of hand because countries are ruled by ruthless dictators. While the use of force may be necessary to address humanitarian crises when all other measures have been exhausted, these actions should be conducted within the framework of accepted international humanitarian law. This framework includes relevant treaties and institutions such as the Geneva Conventions and their Additional Protocols, the United Nations Security Council, and the newly established International Criminal Court.

As modern war becomes more technologically sophisticated and targeting more precise, it is essential not to succumb to the idea that the damage on the ground is also precise and limited. It may be in some cases, but precise bombing does not always yield precise or limited damage. As this study indicates, the health and environmental consequences of precision bombing can affect unborn generations far into the future, even when the bombs are entirely successful in finding their targets. Does such precision warfare meet the standards of so-called "humanitarian interventions" or humanitarian law? This is a pressing and urgent question as the specter of modern war casts a longer and more troubling shadow over world affairs. IEER hopes this report will contribute to a rigorous public debate by raising important questions about some of the more disquieting consequences of modern war.

Sriram Gopal
Nicole Deller
Arjun Makhijani
October 2002

[3] Rizer, 2001.

Executive Summary

On March 23, 1999, the 19 countries of NATO authorized air strikes against Yugoslavia and Operation Allied Force began the following day. This campaign marked the second time that NATO had engaged in an offensive operation in its 50-year existence. This report examines some of the environmental effects of the bombings during the 1999 NATO-Yugoslavia War, primarily in two case studies. There were several instances during this conflict where vital parts of the industrial infrastructure of Yugoslavia were deliberately targeted and bombed by NATO forces. This had a two-fold effect on the local civilian populations. First, vital facilities were rendered inoperable and second, the persistent pollution created by the destruction of these facilities was left to fester for months and may affect large numbers of civilians over a widespread area in coming years. Two specific cases of NATO bombings are examined in order to look at the type and range of environmental damage resulting from precision bombing. We selected the cases from among those where the precision bombing worked according to the following criteria:

- a specific geographically precise target was picked out well ahead of the bombing run;
- the bombing run successfully destroyed the target in question, with little direct blast damage to facilities not intended to be damaged;
- direct casualties among NATO forces, as a result of the bombing runs, were zero and civilian casualties were low.

It is hoped this study will help future efforts to assess the environmental impacts of war. Our case studies were facilitated to some extent by the United Nations Environmental Program Balkans Task Force (UNEP/BTF), which had previously studied the two chosen sites: the industrial facilities in Pancevo and the Zastava factory in Kragujevac. These are two of the four sites that UNEP designated as environmental "hot spots" as a result of the bombings.[4] But we still faced serious challenges to our research. The data required for a thorough analysis was not available either because it did not exist, or because it was not available to the public.

In Pancevo, the bombings resulted in major releases of 1,2-dichloroethane and mercury, pollution created by bomb-related fires, and other environmental damage. In Kragujevac, environmental concerns surround PCB spills that resulted from bombed transformer stations. The environmental damage caused by the bombings of these facilities is described, in detail, in this report.

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[4] The other two hot spots are Novi Sad and Bor. Novi Sad, a city of 1 million, is home to a major oil refinery where bombings led to the spilling and burning of thousands of tons of oil upstream of the city's municipal water extraction point. Bor is an industrial site that serves a variety of industries, including a copper mine, smelting plant and an oil depot. UNEP, 1999, pp. 43 to 51.

Additionally, the strategy of bombing industrial facilities is examined as it relates to customary international humanitarian law. There is a great deal of debate among scholars and officials as to whether the NATO action as a whole and the specific bombings analyzed in this report complied with international law. There is enough evidence, however, to suggest that NATO may have violated the fourth Geneva Convention as well as Additional Protocol I to the Geneva Convention.

Main Findings

1. ***To date, there is insufficient data to accurately quantify the effect that the bombings have had or will have on the environment and on public health, or both.***

Given the lack of pre-conflict pollution data, no baseline levels could be established. Therefore, it is impossible to determine exactly how much pollution was caused by the NATO bombings and what adverse public health effects can be expected. In order to do this assessment, environmental and public health monitoring data must be made available to the public so that comparisons can be made between pre-war and post-war conditions.

2. ***The NATO bombings did result in the release of significant amounts of toxic substances and exacerbate existing conditions that were not ideal by all accounts.***

The bombings in Pancevo resulted in a 1,2-dichloroethane release and mercury release, both of which pose potentially long-term threats to the local population and local environment. These examples clearly illustrate the unintended effects that can result from the bombing of a chemical facility even when precision weapons are used and perform according to specifications.

3. ***The cleanup process has been made more costly and possibly more risky to the public because of the long delay in starting the clean-up process.***

As time passed and aggressive cleanup was delayed, the problems of environmental remediation became increasingly complex due to the spread of the contaminants. UNEP admits that cleanup needed to happen sooner rather than later: "[t]he costs associated with environmental clean-up and remediation increase overtime [sic] due to increased infiltration or spread of chemical contaminants."[5]

4. ***The health risks to civilians may be increased as a result of the NATO bombings.***

Civilians can be exposed to these pollutants via several pathways that include inhalation, the use of contaminated groundwater, and the consumption of contaminated fish. While in some cases the exposure is not immediate, there is a definite public health risk over time.

[5] UNEP, October 2001, p. 5.

5. ***The data necessary to characterize the present situation in Pancevo and Kragujevac are lacking***.

Monitoring data was either not made available or does not exist. It is impossible to conclude definitively what are the major risks and how many of these risks exist today due to the bombings. As of this writing, the most recent data that could obtained for this report is almost two years old. As a result, the current risks to public health and the environment can only be estimated.

6. ***Monitoring and cleanup programs are urgently needed in Pancevo and Kragujevac***.

Monitoring programs will certainly help fill many of the gaps described in this report. However, monitoring does not equal remediation. Urgent steps need to be taken in order to ensure that the problems do not worsen.

7. ***Persuasive evidence indicates that humanitarian law may have been violated in the NATO bombing campaign, notably with respect to the bombing of Pancevo.***

A number of aspects of international humanitarian law, particularly the 1977 Additional Protocol I to the Geneva Convention, restrict the bombing of civilian facilities. However, because the U.S. government has refused to release its targeting criteria or the military objectives that were accomplished by the bombing of these facilities a definitive conclusion is difficult to reach as to the legality of the targeting of some facilities at Pancevo and Kragujevac.

Recommendations

1. ***The entire issue of bombing civilian facilities to accomplish military objectives needs to become the subject of a rigorous public inquiry. Such an inquiry should include consideration of immediate and/or environmental and health damage that could be inflicted on the country or in neighboring countries sharing ecosystems with the countries at war.***

Such an inquiry is urgently needed because it relates to the specific bombings that are covered in this report and because precision bombing is evolving into a principal component of military strategy adopted by NATO members. Other countries may also adopt precision bombing in the future.

2. ***Environmental cleanup needs to be expedited so as to close the time gap between the conflict and remediation.***

At the time of this writing, over three years have elapsed since the bombings ended in 1999. Only in recent months have sincere, large-scale remediation efforts begun. The main reason given is a lack of funds to specifically cover for cleanup costs. UNEP, or

some other international body, should develop a system whereby funds can be allocated immediately in the case of a severe environmental problem. Even if a country's regime is not politically desirable, its people should not have to suffer long-term consequences to their environment.

3. Information regarding past bombings of civilian industrial facilities should be available to the public for legal review.

A thorough legal review under international humanitarian law of bombings such as those in Pancevo and Kragujevac cannot take place without the full disclosure of information by the militaries that carried out those attacks, including information on the rationale for choosing these targets. Such disclosure would foster trust between the public and military by allowing the military to prove that these attacks were necessary to achieve concrete military objectives.

4. Until such time as the United States recognizes the legal prohibitions on environmental damage during wartime, the United States should conduct no bombings of civilian industrial facilities containing any dangerous substances likely to be released into the environment.

The United States should ratify Additional Protocol I to the Geneva Conventions relating to the protection of victims of international armed conflicts and join the International Criminal Court which has jurisdiction to prosecute violations of these protections. At minimum, the United States should acknowledge that the prohibitions of methods of warfare intended or likely to cause severe environmental damage have developed into binding customary law. Future bombing of civilian industrial facilities that could release dangerous substances into the environment or cause long-term damage to health and the environment would raise the same questions of legality as those in Pancevo and Kragujevac. Until such time as the United States has adopted the international legal framework on the protection of victims of international armed conflicts as binding upon itself, it should not bomb or consider bombing these types of facilities. This recommendation applies to any similarly situated country outside of the existing legal framework.

5. Extensive and on-going monitoring programs should be established to ensure that the cleanup in Yugoslavia is effective and that unknown sources of pollution do not remain in the environment.

Presently, large uncertainties remain about the extent of the pollution (e.g. contamination of the waterways around Kragujevac by PCBs). Monitoring programs should be established immediately to prevent the public's exposure to unforeseen dangers. Furthermore, these monitoring programs would measure the effectiveness of the cleanup and ensure its thoroughness.

6. The cleanup process should be more transparent.

The public, whether it be the people living in Yugoslavia or other interested parties, should have greater access to information on the status of cleanup activities and the health of the local environment. Such openness would foster trust between the institutions carrying out the cleanup and those whom they are trying to protect. UNEP stresses the importance of openness as one of the lessons learned from its first year of operations in Yugoslavia. It states that "ownership, availability, and distribution of data during clean-up activities should be clearly defined between all relevant stakeholders including industrial partners, workers, municipalities, environmental authorities, etc. This will ensure the efficient implementation of cleanup activities with decisions on remediation activities taken with all possible data available."[6]

[6] UNEP, October 2001, p. 5.

Chapter 1: Introduction

In today's military climate, much praise is given to "surgical" or "precision" warfare. Gone are the days when fleets of bombers would raze a city by dropping thousands of tons of explosives. During the Persian Gulf War, we became accustomed to seeing blurry black and white images of a factory or bridge being destroyed in a massive explosion. But when these factories were bombed, did the damage end there?

With the proliferation in the production and use of long-lived organic chemicals over the past several decades, the bombing of factories and chemical plants has become a dangerous proposition with consequences that could last for decades or longer. To examine the consequences of precision targeting of industrial facilities even when it works as designed, we examined two facilities that were bombed during the 78-day NATO-Yugoslavia war in 1999 through on-site interviews and the study of available data.

A. Post Cold War Yugoslavia and Operation Allied Force

When the Berlin Wall fell in 1989, Yugoslavia was further along than all other East European countries in making the transition to a market economy and closer foreign relations with the West.[7] These relations were even evident during and just after World War II when Yugoslavia acted as a founding member of the United Nations as well as a participant in the 1944 Bretton Woods Agreements, which eventually established the World Bank.[8] During much of the Cold War, under the non-aligned foreign policy of Josip Broz Tito, Yugoslavia had implemented market reforms that made it eligible for loans from the International Monetary Fund (IMF) and World Bank, in addition to membership to the General Agreement on Tariffs and Trade (GATT).[9] Yugoslavia was the only Eastern Bloc country that was afforded "Most Favored Nation" trade status by the United States.[10] The steps taken toward political decentralization and economic reforms led to associations with the European Community and the European Free Trade Association.[11] In two years, the country as it stood then would cease to exist.

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[7] On March 14, 2002, the remaining states of Yugoslavia, Serbia and Montenegro, reached an agreement that officially changed the name of the country to "Serbia and Montenegro". Under this agreement, Serbia and Montenegro would share a military and one seat at the United Nations while maintaining separate governments, currencies, and customs services. Because the events described in this report took place well before this change occurred, the author decided to continue to refer to the country as Yugoslavia. See CNN, 2002.

[8] UN Charter, 1945; Bretton Woods, 1944.

[9] Woodward, 1995, pp. 1, 25.

[10] ITDS, 2002. The terminology has now changed. What was formerly known as Most Favored Nation status is now referred to as Normal Trade Relations.

[11] Woodward, 1995, p. 1. The European Community is a precursor to the present-day European Union. The name change took place after the Maastricht Treaty on the European Union entered into force on November 1, 1993. See Europa, 2002.

In 1991, the republics of Macedonia, Slovenia, and Croatia all declared their independence from Yugoslavia with Bosnia-Herzegovina following in 1992.[12] After these violent wars of secession, Yugoslavia found itself with just two remaining provinces, Montenegro and Serbia. At the southern end of Serbia lies the province of Kosovo, which in turn is bordered by Montenegro, Albania, and Macedonia (see Figure 1). Kosovo, a semi-autonomous region under Tito, has a majority Albanian population. In 1953, Kosovo's population was approximately 65% Albanian. The last census was taken in 1991, but it was boycotted by the Albanians. The official estimate for 1991 put the Albanian population at 82%, but some estimates are as high as 90%.[13]

Under Tito, Kosovo had enjoyed certain privileges because of its large Albanian population but these privileges were repealed in 1989 by, then-president of Serbia, Slobodan Milosevic (he became president of all Yugoslavia in 1997). According to polls, by 1995 an overwhelming number of Kosovars wished to join Albania or have an independent state of Kosovo.[14] The situation came to a head in 1998 when Serb security forces cracked down on the Kosovo Liberation Army (KLA), a separatist guerilla movement. The stated goal of Serbian forces was to prevent the further disintegration of Yugoslavia while the KLA was trying to force Kosovo's independence through military action. There was a parallel independence movement within Kosovo, that favored peaceful resistance, led by Ibrahim Rugova,.[15]

The ensuing violence led to international diplomatic intervention. An international agreement reached in October 1998 was to allow 2,000 unarmed verifiers under the auspices of the Organization for Security and Co-operation in Europe (OSCE) to enter Kosovo with diplomatic immunity in order to ensure the pacification of the province.[16] Despite this agreement, violence continued and a last ditch attempt at a peaceful resolution disintegrated at a conference in Rambouillet, France in early 1999.[17]

On March 23, 1999, the 19 countries of NATO authorized air strikes against Yugoslavia and Operation Allied Force began the following day.[18] This campaign marked the second time that NATO had engaged in an offensive operation in its 50-year existence.[19] The action was taken without the approval of the United Nations Security Council.[20] Over the next two and a half months, targets were attacked all over Yugoslavia. Initial air strikes were launched with the assumption that the conflict would not be drawn out because the attacks would force Milosevic to quickly capitulate to NATO's demands.[21] In reality, they had the opposite effect, whereby Serbian forces accelerated the expulsion of

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[12] CIA World Factbook, 2001.
[13] Gjonça, 1999, Table 2.
[14] Daaldar and O'Hanlon, 2000, p. 8.
[15] Daaldar and O'Hanlon, 2000, p. 22.
[16] Daaldar and O'Hanlon, 2000, pp. 48,49.
[17] Daaldar and O'Hanlon, 2000, pp. 77-84.
[18] UNEP, 1999, p. 12; Daaldar and O'Hanlon, 2000, p. 101.
[19] Peters, *et al.*, 2001, p. xiii. NATO's first offensive operation was Operation Deliberate Force which was conducted in Bosnia from August 29 to September 14, 1995.
[20] Daaldar and O'Hanlon, 2000, p. 102.
[21] Daaldar and O'Hanlon, 2000, p. 101.

Kosovar Albanians. Air strikes were then redirected to inflict damage on the Serbian infrastructure and its war-making capability.

The bombings resulted in large-scale physical damage and approximately 500 civilian deaths in Serbia.[22] In addition, 800,000 Kosovars fled the NATO bombs or were forcibly displaced by Serbian para-military units to Macedonia, Albania and neighboring countries; as many as 500,000 were displaced internally. Death toll estimates of Kosovar Albanians from Serbia's campaign into Kosovo range from 5,000 to 11,000.[23]

On March 30, 1999, then Yugoslav President Slobodan Milosevic offered to withdraw some troops from Kosovo if NATO agreed to halt the air campaign. The offer was rejected and NATO demanded a full withdrawal from Kosovo. In addition, Milosevic demanded that NATO air strikes would have to end before peace talks could begin. This offer was rejected as well.[24] On April 9th, United Nations Secretary-General Kofi Annan outlined five conditions that would bring about an end to the conflict. These conditions were:

1. an end to the violence in Kosovo,
2. withdrawal of Yugoslav forces from Kosovo,
3. deployment of an international peacekeeping force to the area,
4. return of the Kosovo Albanian refugees, and
5. resumption of negotiations for a political solution.[25]

On June 3, 1999, the Yugoslav government and the Serbian parliament agreed to a peace plan that was negotiated in Germany. On June 9th, NATO and Yugoslav military commanders came to terms on the Yugoslav withdrawal. NATO suspended Operation Allied Force on June 10, 1999.[26]

In this report, we examine some of the environmental effects of the bombings during the 1999 NATO-Yugoslavia War, primarily in two case studies.[27] There were several instances during this conflict where vital parts of the industrial infrastructure of Yugoslavia were deliberately targeted and bombed by NATO forces. This strategy had a two-fold effect on local civilian populations. First, vital facilities were rendered inoperable and second, the destruction of these facilities released persistent pollutants that have the potential to affect large numbers of civilians over a widespread area in coming years. We will examine two specific cases of NATO bombings in order to look at the type and range of environmental damage resulting from precision bombing. We selected the cases from among those where the precision bombing worked according to the following criteria:

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[22] HRW, 2000, p. 2.
[23] Daaldar and O'Hanlon, 2000, pp. 108 to 110..
[24] CNN, 1999a.
[25] UNEP, 1999, p. 15.
[26] UNEP, 1999 pp. 20, 21..
[27] The conflict will be referred to as a war even though war was never formally declared on Yugoslavia by any member of NATO.

- a specific geographically precise target was picked out well ahead of the bombing run;
- the bombing run successfully destroyed the target in question, with little direct blast damage to facilities not intended to be damaged;
- direct casualties among NATO forces, as a result of the bombing runs, were zero and civilian casualties were low.

In addition to these criteria, we chose facilities that had toxic materials on-site, such as PCBs and other organic compounds, so that we could examine the impact beyond the direct blast effects on destroyed facilities. This focus further narrowed the potential targets that we could use in the case studies, but it does typify a large class of targets in the 1999 NATO-Yugoslav war.

It is hoped this study may be helpful to future efforts in assessing the environmental impacts of war. Our case studies were facilitated to some extent by the United Nations Environmental Program Balkans Task Force (UNEP/BTF), which had previously studied the two chosen sites: the industrial facilities in Pancevo and the Zastava factory in Kragujevac. These are two of the four sites that UNEP has designated as environmental "hot spots" as a result of the bombings.[28] But we still faced serious limitations on our work.

Each of these facilities was bombed multiple times and each was destroyed with little direct harm to civilian life or property compared to non-precision strikes – there were three civilian deaths in Pancevo's oil refinery. The targets were specifically chosen to cripple the Serbian infrastructure in order to degrade its war-making capability. According to General Wesley Clark, then NATO's Supreme Allied Commander:

> "The military mission…is to attack Yugoslav military and security forces and *associated facilities* with sufficient effect to degrade its capacity to continue repression of the civilian population and to deter further military actions against its own people. We are going to systematically attack, disrupt, degrade, devastate, and ultimately destroy these forces *and their facilities* and support, unless President Milosevic complies with the demands of the international community."[29] (emphasis added)

For the reasons cited, these two case studies present a suitable choice for studying the large-scale and long-term effects of precision targeting. By deliberately excluding bombs that went astray, we can focus on the effects of modern precision bombing when it works as intended.

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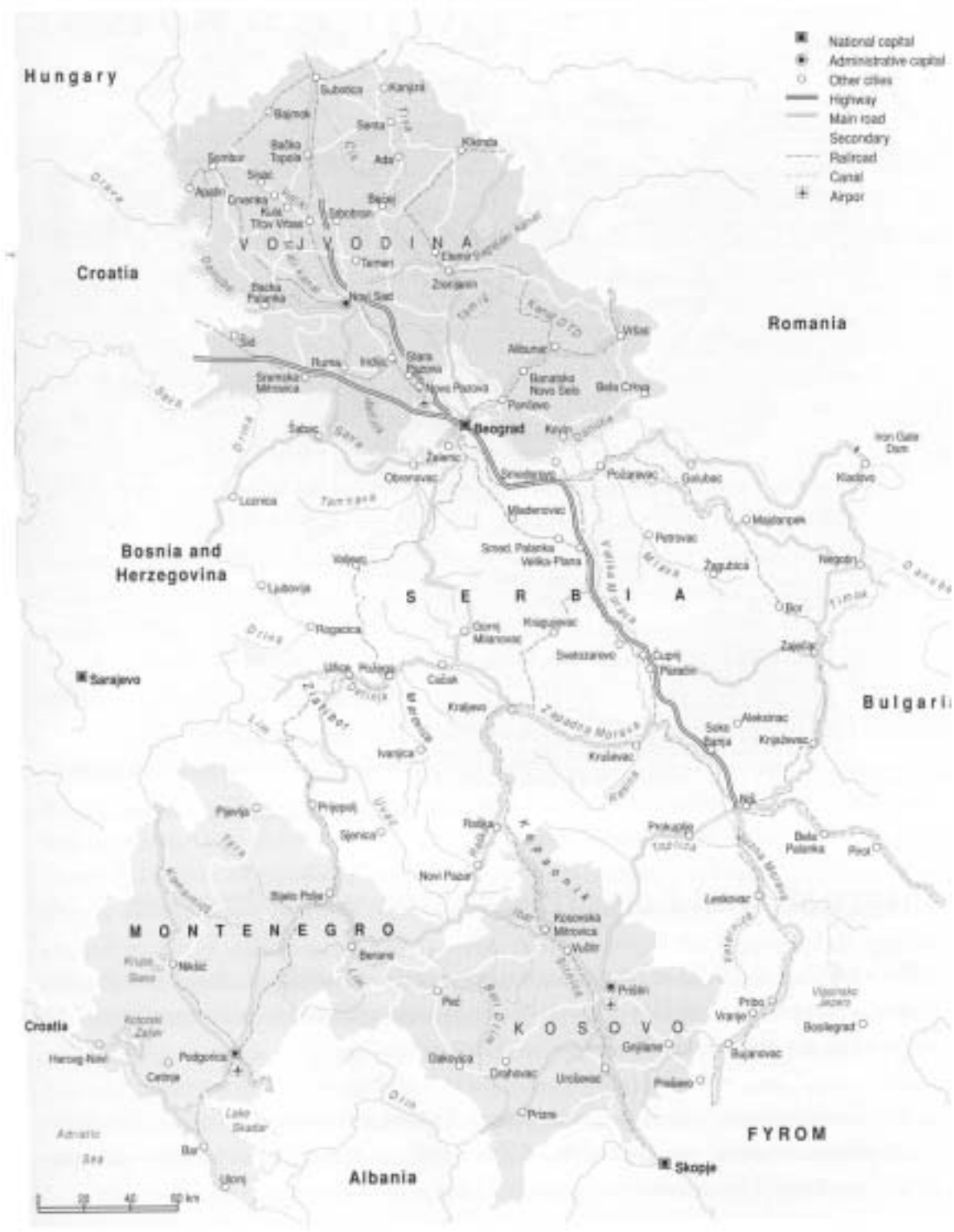
[28] The other two hot spots are Novi Sad and Bor. Novi Sad, a city of 1 million, is home to a major oil refinery where bombings led to the spilling and burning of thousands of tons of oil upstream of the city's municipal water extraction point. Bor is an industrial site that serves a variety of industries, including a copper mine, smelting plant and an oil depot. UNEP, 1999, pp. 43 to 51.

[29] Clark, 2001, p. 203.

The complex at Pancevo houses a fertilizer plant, a petrochemical plant, and an oil refinery and stands on a canal that feeds the Danube River. The Danube is the second longest river in Europe (after the Volga) and is a vital environmental and economic resource to central and eastern Europe. Its source is in the Black Forest region of Germany and it empties into the Black Sea.[30] All three of the facilities suffered major damage that led to the burning or spilling of large amounts of 1,2-dichloroethane, ammonia, oil, vinyl chloride, and other chemicals. The Kragujevac industrial complex consists of several dozen small factories that produce a wide range of products. The complex is often identified as home to the Zastava automobile and truck factory. Several buildings in the complex sustained damage and the resultant spills and fires released significant amounts of polychlorinated biphenyls (PCBs), oil products, coolants, and a variety of other chemicals. The range of conditions and chemicals found at Pancevo and Kragujevac is large enough to enable us to arrive at preliminary conclusions as to potential environmental impacts of this type of precision bombing.

[30] Encarta, 2002.

Figure 1: A Map of the Federal Republic of Yugoslavia



Source: Adapted from UNEP, 1999, p. 6.

B. Pancevo Industrial Complex

Setting

Pancevo is an industrial town with a population of about 80,000 to 90,000 located in the province of Vojvodina in the republic of Serbia, which was part of the former Federal Republic of Yugoslavia. It is located 20 kilometers northeast of the capital of Belgrade (population 1.2 million) at the confluence of the Tamis and Danube rivers. The industrial complex covers about 290 hectares and lies to the south and southeast of Vojlovica, a major residential area in Pancevo. The complex is home to the HIP Azotara chemical fertilizer factory, the HIP Petrohemija petrochemical plant, and the NIS Oil Refinery (see Figure 2).[31] The three factories employ 10,000 people and, as such, represent the major employer for the entire Pancevo area. Directly to the south of the industrial complex lie several small villages.[32] Between 1992 and 1996, the three plants were shut down because of foreign trade sanctions. Only the refinery would run from time to time, with crude oil supplied from domestic oil production.[33]

HIP Azotara was founded in 1962. The factory produces and/or handles many chemicals including ammonia, nitric acid, urea, calcium ammonium nitrate fertilizers, and NPK fertilizers (NPK stands for nitrogen, phosphorus, and potassium).[34] HIP Petrohemija was constructed between 1971 and 1974. It produces 1,2-dichloroethane (also referred to as EDC or DCA) which is used to make vinyl chloride monomer that is polymerized to make polyvinyl chloride (PVC). Initially, chlorine is needed to produce 1,2-dichloroethane, and the process this plant uses to produce chlorine, the chlor-alkali process, involves the use of mercury.[35] Finally, the NIS oil refinery, the largest in the former Yugoslavia, is a facility that produces oil and gasoline products that are used by a variety of industries. These plants were constructed using American aid and cutting-edge technology made available at the time of construction.[36]

The petrochemical plant and the oil refinery are linked to the Danube via a 1.8-kilometer channel into which treated wastewater is released.[37] The fertilizer factory uses an adjacent drainage canal.[38] Before the conflict, wastewater from the petrochemical plant and refinery was treated by a two-step process (separation and biological treatment)

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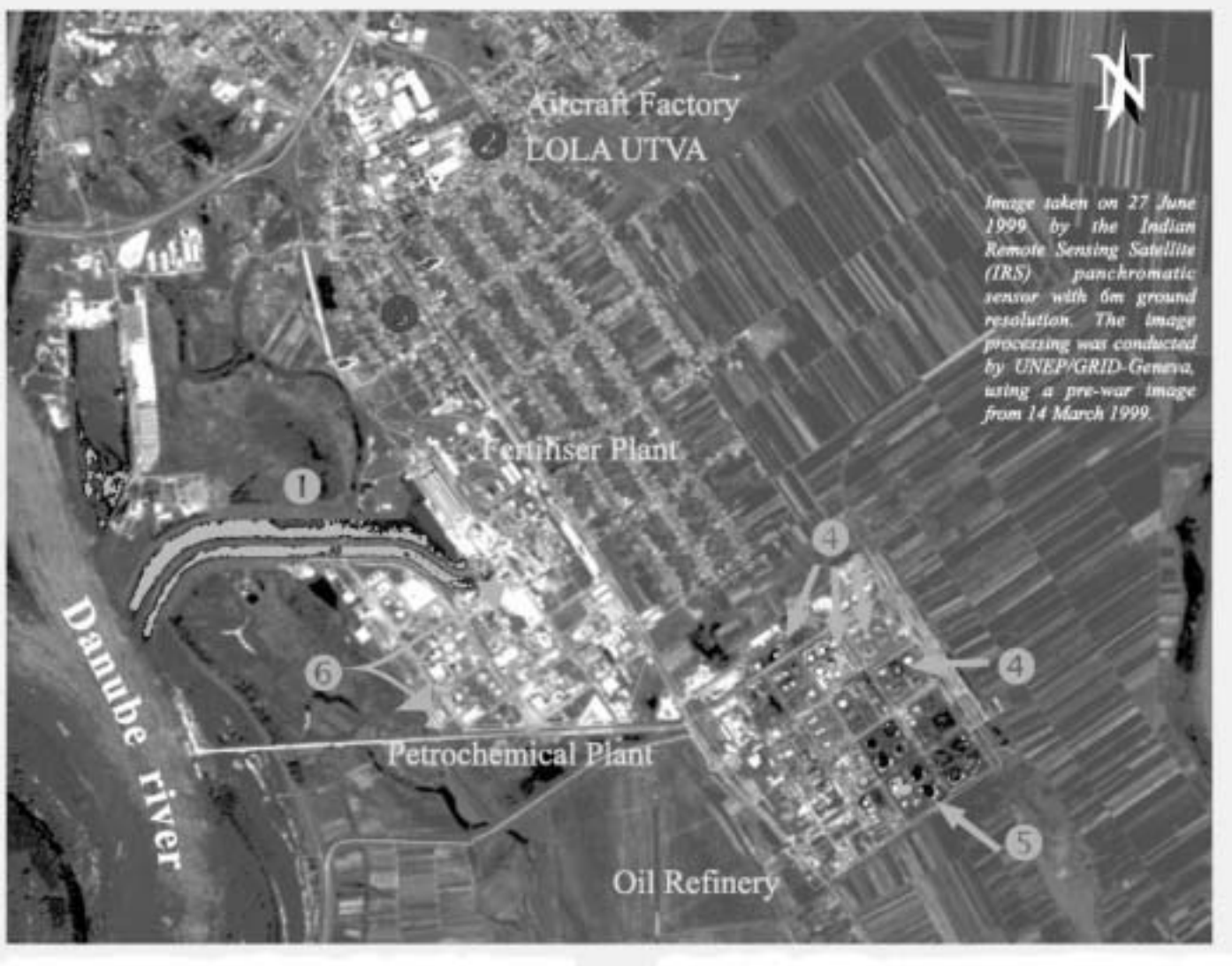
[31] OMEGAM, 2000, p. 7; BTF, 1999a, p. 4; UNEP, 2000, p. 27; FOCUS, 1999, Part II, p.1 gives a population of 130,000.
[32] BTF, 1999a, p. 5.
[33] Kandic, 2001.
[34] BTF, 1999a, p. 8. Calcium ammonium nitrate is a mixture of ammonium nitrate with calcium carbonate and/or dolomite containing not more than 80% of ammonium nitrate, not less than 20% nitrogen, and not more than 0.4% of total combustible material. EFMA web site.
[35] BTF, 1999a, p. 10. In this process, chlorine and sodium hydroxide are produced through the electrolytic decomposition of salt. The overall equation is $2NaCl + 2H_2O \rightarrow Cl_2 + H_2 + 2NaOH$. Mercury is used as the anode of the electrolytic reaction. Cheresources, 2002.
[36] Porobic, 2001; UNEP, 2000, Section I, Pancevo, p. 27; OMEGAM, 2000, pp. 18, 19; UNEP, 1999, p. 31.
[37] UNEP, 1999, p. 31.
[38] OMEGAM, 2000, p. 7.

before being released into the wastewater channel.[39] This facility was considered the best wastewater treatment facility in the former Yugoslavia.[40]

A drinking water extraction plant lies just upstream of Pancevo's industrial site on the Danube River near the point where the Tamis River meets the Danube.[41] The wells draw water from the lower part of the main (lower) aquifer.[42] The water removed from the aquifer is treated by aeration, filtration, injection of ozone, and chlorination. This extraction point serves the majority of people in the area around Pancevo. However, a significant number of people (about 5% in town and 10% in surrounding villages) use private wells for drinking water, crops, and gardens.[43]

[39] Mirkov, 2001; OMEGAM, 2000, pp. 18, 19; UNEP, 1999, p. 31.
[40] Kandic, 2001.
[41] OMEGAM, 2000, p. 7.
[42] BTF, 1999a, pp. 5, 6.
[43] BTF, 1999a, p. 5; UNEP, 2000, Section 2-Pancevo, p. 2.

Figure 2: Satellite image of the Pancevo Industrial Complex



Source: UNEP, 1999, p. 36
Note: The numbers indicate areas where damage was visible from satellite image (picture taken June 27, 1999).

The bombings of the facilities in Pancevo occurred over a period of several weeks and were critically disruptive to life in Pancevo. After the initial bombing of the petrochemical complex, an estimated 40,000 people left the city and 30,000 of them returned only after the bombings had ended in June.[44] However, UNEP reports that 80,000 people were evacuated from Pancevo and its surrounding communities on April 18th because of the high concentrations of toxic fumes, soot, and smoke that were present

[44] Bancov, 1999.

in the air.[45] In addition, a temporary ban was placed on fishing in the Danube near Pancevo until the fall of that year.[46] Serbia's Ministry of the Protection of Human Environment recommended that no produce grown in the areas around Pancevo be consumed as there was a good deal of rain that washed soot and other matter from the fires in Pancevo onto surrounding agricultural areas.[47]

Hydrogeology of the area

It is important to understand the hydrogeology of the region in order to estimate the impacts pollutants released as a result of the bombings. The natural soil surface under the site is divided into several layers. The top layer is a loamy mixture of sand, silt, and clay between 1 and 6 meters thick and is considered moderately permeable. Below this layer lies a very permeable, sandy aquifer that goes to a depth of about 15 meters. Below this groundwater source lies the main aquifer that extends to a depth of about 50 meters. A thin and moderately permeable layer separates these two water sources.[48]

The groundwater in the area is greatly influenced by the amount of water in the Danube River. Therefore, the area is normally covered with swampy patches that result from the groundwater rising close to the surface. This type of terrain is not suitable for an industrial site, therefore, HIP Petrohemija was built on top of a 6-meter thick layer of sand, while the refinery was built on 6-meter thick layer of material that is about 10% clay, 10-35% sand, and 65-85% silt. Within this layer, an artificial aquifer has developed; here, the groundwater comes very close to the surface during periods of heavy rainfall.[49] In addition, because of the large influence the Danube has on groundwater sources, the groundwater flow is considered to be complex and not very well understood.[50] Those who have studied the Pancevo region state that the area is conducive to downward movement of groundwater and also any pollutants in the water.[51]

The FOCUS group (a private, multi-national organization based out of Switzerland) reported that measurements taken before and after the war showed no important differences in the well water except in its turbidity and color.[52] This difference is attributed to the fact that the samples were taken at different times of the year (i.e., fall versus summer) when the groundwater is at different levels. The groundwater also shows high ammonia levels that are characteristic of oxygen-deficient water.[53]

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[45] BTF, 1999a, p. 4.
[46] Milovati, 2001.
[47] Bancov, 1999.
[48] UNEP, 2000, Section 2-Pancevo pg. 2; OMEGAM pg. 13; Lozajic, *et al.,* 2000.
[49] UNEP, 2000, Section 2- Pancevo, pg. 2.
[50] UNEP, 2000, Section 2-Pancevo, pg. 2..
[51] Dekonta-Aquatest, 2001, p. 3.
[52] FOCUS, 1999, Part II, p. 1. FOCUS was an organization created between the Swiss, Russian, Austrian, and Greek governments in order to perform independent assessments that evaluate the consequences of conflict in the fields of health care, environment, construction, and economics. FOCUS was later renamed Swiss Disaster Relief and then was renamed again to the Swiss Agency for Development and Cooperation.
[53] FOCUS, 1999, Part II, p. 1. Under anoxic conditions microbes are not able to convert ammonia to nitrogen oxides as part of the nitrogen cycle.

Pre-conflict levels of pollution

During on-site interviews, officials from the refinery and petrochemical plant stated that routine environmental and health monitoring continues to be carried out; however, none of this data was made available. Therefore, it is impossible to quantitatively establish pre-conflict levels of pollution. Most of the data presented in this report is from measurements taken immediately after the bombings. Previous monitoring data was not obtained for one of two reasons: a) it simply does not exist because lack of funds, working equipment, or some other reason made it impossible to take the necessary measurements; or b) the data is not available to the public.

Even before the bombings, Pancevo and its immediate surroundings suffered from chronic pollution. This assertion is based on conversations with several scientists in Belgrade in addition to some specific scientific evidence that oil pollution did exist at the refinery prior to the bombings.[54] For example, at the petrochemical plant, chlorinated solvents (e.g., trichloromethane, tetrachloromethane, trichloroethane, dichloroethene, trichloroethene, and others) were found in both soil and groundwater samples. These pollutants are often associated with PVC production as unwanted by-products. Some of the levels of these pollutants measured at HIP Petrohemija exceeded values set by international guidelines.[55] Moreover, the town of Pancevo has a higher than usual incidence of angiosarcoma, a rare type of liver cancer.[56] There is a link between this form of cancer and vinyl chloride.[57] In addition, there is evidence of a previous mercury spill that was far larger than the one that resulted from the NATO bombings as well as previous polychlorinated biphenyl (PCB) contamination in the waste channel.[58] Finally, there was a major 1,2-dichloroethane spill some years before the conflict that hindered any attempts to evaluate the impacts of the contamination that resulted exclusively from the bombings.[59]

One of the analytical difficulties of analyzing the data associated with the complex is to distinguish the important pre-conflict problems in Pancevo with the significant impacts that resulted from the bombings. This area had already been exposed to many pollutants in all media; the bombings placed an additional huge stress on this already vulnerable system.

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[54] Jovancicevic, *et al.*, 1997; Jovancicevic and Polic, 2000; Vukmirovic, 2001.
[55] BTF, 1999a, pg. 25-27.
[56] Bikar, 2001; Vukmirovic, 2001.
[57] ATSDR, 1997b, p. 54; UNEP, 1999, p. 88.
[58] BTF, 1999a, pp. 39, 40.
[59] Lozajic, 2002.

C. Kragujevac Industrial Complex

Setting

Kragujevac (population 150,000) is an industrial town located in central Serbia and home to the Zastava industrial complex.[60] The complex is actually made up of dozens of smaller companies and it produces everything from heavy machinery, to cars and trucks, to hunting rifles. At one point, the plant manufactured heavy equipment and arms for the military; but according to factory management, that was not the case at the time of the bombings.[61] Before the onset of economic sanctions, this was one of the largest industrial facilities in the Balkans and consequently, the factory played a huge role in the lives of the city's inhabitants. The factory employed 56,000 people before foreign trade sanctions were imposed and, as of April, 2001 employed 30,000.[62] About one-half of the employees, as of 2001, are on "paid leave," i.e., they are out of work but are still receiving a small monthly stipend.[63]

The factory was built on the Lepenica river, a tributary of the Velika Morava. The Morava then meets the Danube 60 kilometers downstream of Belgrade.[64] According to factory managers, since its construction the factory had operated under a very active environmental management system that was accredited under the ISO 14000 environmental management standard (see footnote).[65]

The factory was bombed on the April 9th and 12th, 1999. On the March 27th, that same year, Zastava workers issued an open letter stating that they would form a human shield in order to fend off an aerial assault.[66] When the bombings did occur on April 9th, as many as 124 civilian workers were injured. It is not clear if they were still acting as human shields when this took place.[67] It is also important to note that under international humanitarian law, civilians are not to be used as shields that render a target immune from attack, but it is not clear whether this rule applies in those cases where civilians voluntarily form a shield, as seems to be the case here.[68] Legal issues are discussed in greater detail in Chapter 5.

Hydrogeology of the area

Unlike Pancevo, there was no detailed information available regarding the underground water resources of the areas around Kragujevac.

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[60] UNEP, 1999, p. 38.
[61] Nedeljkovic, 2001.
[62] Erlanger, 2001, Nedeljkovic, 2001.
[63] Erlanger, 2001.
[64] UNEP, 1999, p. 38.
[65] UNEP, 1999, pp. 38, 39. ISO (The International Organization for Standardization) is "a private sector, international standards body based in Geneva, Switzerland. Founded in 1947, ISO promotes the international harmonization and development of manufacturing, product, and communications standards." See Envirosense, 2002.
[66] Zastava, 1999.
[67] Walker, *et al.*, 1999.
[68] Zastava, 1999; Geneva, 1949, Article 28.

Pre-conflict levels of pollution

As in Pancevo, this area was probably exposed to significant levels of pre-conflict pollution. Any pre-conflict pollution data that might exist was not made available. Inquiries for this data were made to representatives of the Zastava factory as well as to city officials.

The waterways around the plant may have been contaminated with PCBs from a source other than the transformers that were bombed during the attack, but there is some debate about this.[69] Sediment samples taken from the Lepenica River after the bombings were contaminated with PCB. However, the chemical composition of the PCBs was different than that which was found in the Kragujevac factory transformer oil.[70] This indicates that there must have been multiple sources of pollution to this area. Also, civilian drinking water wells, which are located on the shores of the Morava River, were tested for PCB contamination by neither the city's public health institute nor the United Nations teams.[71]

Samples from the Lepenica River that were taken after the bombings also showed contamination from heavy metals.[72] A mussel sample with a high mercury concentration of 0.49 mg/kg of dry weight was found and analyzed several weeks after the bombings. The U.S. EPA has issued a Tissue Residue Criterion of 0.3 mg/kg of fish for mercury, but only in its organic form (methylmercury).[73] This sample was taken up stream of the site and this also indicates an upstream source of pollution.[74] Yet, in the literature examined for this report, there was no indication of a significant heavy metal release that resulted from the bombings.

[69] BTF, 1999b, p. 4.
[70] UNEP, 2000, Section 3-Kragujevac, p. 1.
[71] Vasilovic, 2001
[72] BTF, 1999b, p. 4.
[73] EPA, January 2001, p. xvi. This Tissue Residue Criterion includes shellfish and is based on a total fish/shellfish consumption rate of 0.0175 kg of fish per day.
[74] BTF, 1999b, p. 6.

Chapter 2: Bombings and Chemical Release at Pancevo

A. Description of Releases at Individual facilities

HIP Petrohemija

The petrochemical plant was bombed on April 15th and 18th, 1999. There are four major environmental issues directly associated with the NATO bombings of HIP Petrohemija.

- First, on April 18th a vinyl chloride storage tank was hit and the 440 metric tons of material that was stored in it burned.[75] An additional 20 metric tons of this known carcinogen was being stored in rail cars for transport; this material also burned.[76] Ironically, the contents of these cars had been sold to and were bound for Hungary, and Hungary demanded that HIP Petrohemija pay for the destroyed items.[77] It should also be noted that there were two vinyl chloride storage tanks on-site, one empty and one full; only the full tank was destroyed.[78]
- Second, when 1,2-dichloroethane storage tanks were indirectly damaged, 2,100 metric tons of 1,2-dichloroethane spilled, with 50% released onto the ground with the remainder entering into the wastewater channel.
- Third, the chlor-alkali plant was heavily damaged and this released 8 metric tons of metallic mercury into the environment. Seven thousand eight hundred kilograms (7.8 metric tons) was spilled on the surface of the site while the remaining 200 kilograms leaked into the waste channel.[79] Most of the material that was spilled onto the soil was recovered, but that is not the case for the mercury that was spilled into the channel. In the United States, the maximum contaminant level (MCL) for mercury in drinking water is 2 micrograms per liter (μg/L, two parts per billion by weight).[80] Two hundred kilograms of material would require 100 billion liters of water in order to dilute it to acceptable levels by U.S. EPA standards.
- Fourth, the wastewater treatment plant that was used by the oil refinery and the petrochemical plant was seriously damaged during the conflict. This was caused by the sudden influx of material into the plant that exceeded its capacity. As of April 2001, almost two years after the end of the bombing, the treatment plant was running only at 20% capacity.[81] These problems are exacerbated by the fact that the major recipient of all these pollutants has been the wastewater channel that feeds into the Danube River.

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[75] 1 metric ton is 1,000 kilograms.
[76] BTF, 1999a, p. 10.
[77] Kandic, 2001.
[78] Kandic, 2001.
[79] BTF, 1999a, p. 11.
[80] EPA, 2002. The MCL is the maximum permissible level of a chemical or radionuclide contaminant in water that is delivered to any user of a public water system. MCLs are enforceable standards set by the EPA.
[81] Porobic, 2001.

The transformer station at the factory was also damaged during this attack. Initially, the director of the company stated in a letter to the Balkans Task Force (BTF) that polychlorinated biphenyls (PCBs) were released from the transformer; however the BTF team, upon arrival, was told that no transformer oil leaked.[82] Soil samples were tested for PCB contamination by UNEP, and it does not appear that the bombings caused any release of PCBs in Pancevo.[83] However, PCBs were detected in the Danube upstream of the industrial site.[84] The origin of this contamination is not clear. It is certain, however, that storage tanks containing sodium hydroxide (50% pure) and hydrochloric acid were damaged and the solution spilled into the wastewater channel and surrounding soil.[85] The company also intentionally burned 1,900 metric tons of ethylene and propylene to prevent them from being bombed and having them explode.[86]

NIS Oil Refinery

The oil refinery was the most heavily bombed site of the three NATO targets located in Pancevo's industrial complex. It was bombed several times in April 1999 and as late as June 8, 1999.[87] Many storage tanks and pipelines were destroyed as a result of the attacks. Approximately 62,000 metric tons of crude oil and oil products burned and 5,000 to 7,000 metric tons leaked onto the soil and into the sewer system (see Table 1). The spills resulted in 100,000 square meters (10 hectares) of contaminated soil within the refinery complex.[88]

[82] BTF, 1999a, p. 10.
[83] BTF, 1999a, p. 29.
[84] UNEP, 1999, p. 37.
[85] BTF, 1999a, p. 11; OMEGAM, 2000, p. 10.
[86] BTF, 1999a, p. 10.
[87] Bancov, 1999.
[88] Mirkov, 2001.

Table 1: Oil products released as a result of the bombing of the NIS Oil Refinery

Substance	Estimated Release (metric tons)[3]
Total Crude Oil and Oil products burned/leaked	80,000
Crude Oil	56,300
LPG (Liquified Petroleum Gas)	200
Aromatics (e.g. benzene, toluene, and xylene)[1]	400
Gasoline	1,500
Motor Gasoline	4,500
Jet Fuel	1,200
Diesel	350
Fuel Oil	7,500
SCC Gas[2]	6,700
Other[2]	1,900

Source: BTF, 1999a, Table 1.3. (Given to BTF by company management)

Note: Footnotes below have been added by the author and are not in the original BTF report

[1]These compounds are often used as petroleum additives during the refining process.

[2]Many unsuccessful attempts were made at trying to identify the compounds in these categories. The term SCC is often used as an abbreviation for "Standard Classification Code," an identification number assigned to each specific petroleum product. It could also be a typographical error as the term FCC (fluid catalytic cracking) is used to describe gasoline that has undergone a specific type of refining process.

[3]Attempts were also made to find the ratio of leaked product to burned product for each of these categories. However the only response given by factory officials was that approximately 75,000 metric tons of "oil products" burned.

HIP Azotara

HIP Azotara was bombed twice, on April 15 and April 18, 1999. Factory staff informed BTF inspectors that there was great concern over the ammonia storage tank that held 9,600 metric tons of ammonia prior to the bombings.[89] Were this tank to have been struck by a bomb, it would have released enough ammonia to kill many people in the surrounding area. During the bombings, the Public Health Institute of Belgrade took air pollution measurements and these results were made available to UNEP.

The HIP Azotara factory did not possess the capability to transfer the ammonia to another location. As a result, fertilizer production was increased in the early days of the bombings (which began on April 4, 1999) in the hope that this would deplete the amount of ammonia left in storage. By the time of the first attack, the amount of ammonia left in storage was approximately 250 metric tons. The remaining liquid was intentionally dumped directly into the wastewater canal to prevent it from being released into the atmosphere after an explosion. This was done after the ammonia tank was indirectly hit by debris from a separate explosion. In addition to this release of ammonia, 200 to 300 metric tons of calcium ammonium nitrate, phosphates, and potassium chloride leaked or burned as a result of storage tanks being damaged during the bombing (the ratio of leaked material to burned material is not known).[90]

[89] BTF, 1999a, p. 8.
[90] BTF, 1999a, p. 9.

Finally, railway cars carrying about 150 metric tons of crude oil were hit. No attempt was made to extinguish the resulting fires. It is not known whether any oil was spilled from these rail cars. As a first approximation one may assume that all of the oil burned.[91] See Table 2 for a summary of the pollutants that were released from the Pancevo industrial complex.

Table 2: Summary of pollutants released as a result of the 1999 bombings in Pancevo

Substance	Location	Amount Released (metric tons)	Emission Route
Ammonia	HIP Azotara	250	Waste channel
Calcium ammonium nitrate, phosphates, potassium chloride	HIP Azotara	250	Most burned, some into channel
Crude oil	HIP Azotara	150	Most burned, some into channel
Vinyl chloride	HIP Petrohemija	460	Burned
1,2-dichloroethane	HIP Petrohemija	2,100	50% to channel, 50% to soil
Mercury	HIP Petrohemija	8	7.8 metric tons to soil, remainder to channel
Sodium Hydroxide	HIP Petrohemija	100	Soil and waste channel
Ethyl-, propylene	HIP Petrohemija	1,900	Intentionally burned
Hydrochloric acid	HIP Petrohemija	130	Soil and waste channel
Crude oil and derivatives	NIS Oil Refinery	85,000	80,000 metric tons burned, remainder spilled onto soil

Sources: BTF, 1999a, pp. 8, 9; OMEGAM, 2000, p.10; FOCUS, 1999, p. 2; personal interviews; UNEP, 2000, Section 2-Pancevo, p. 27

[91] BTF, 1999a, p. 9.

B. Water and Soil Pollution

With respect to this section and the following section on air pollution, attempts were made to obtain data that would be helpful in characterizing the problems at hand. Data such as aquifer water volume, groundwater flow rate, surface water flow rate at the time of the bombings, and other forms of data would allow for a more quantitative description of the situation. The hydrology of the area has not been well characterized (or, if it has, the data was not made available) and only now are detailed surveys being conducted. The main purpose of this section and subsequent sections is to quantify the damage caused by the bombings. The threats presented to the public and possible cleanup scenarios will be discussed in Chapter 4.

Soil and groundwater contamination is discussed in tandem because the major long-term threat posed by polluted soil is that it provides constant source of pollution to the aquifers beneath. There is also a short-term hazard to workers, who may be exposed to harmful vapors and fumes. These hazards will be discussed along with the potential health effects of the other pollutants.

HIP Petrohemija

Groundwater and Soil Pollution

The major concern at this plant is the spill of over 2,100 metric tons of 1,2-dichloroethane. Half of the material spilled into the waste channel via the sewer system while half of it spilled onto the soil surface. 1,2-dichloroethane is a dense non-aqueous phase liquid (DNAPL), which means that it does not mix with water, is heavier than water, and therefore will sink.

The 1,2-dichloroethane spill might very well be the single greatest long-term threat in Pancevo. While small quantities of this compound would most likely evaporate, that is not the case with a spill of this size. Table 3 gives the maximum concentration of a variety of organic pollutants found in the groundwater during a sampling mission that took place in May 2000. Figure 3 shows where the samples were taken within HIP Petrohemija. Some of the 1,2-dichloroethane measurements are approaching the solubility limit of 1,2-dichloroethane which is 8,690,000 μg/L.[92] The solubility limit is the concentration at which a given material will no longer dissolve in water. All of these concentrations are well above U.S. regulatory limits. The U.S. EPA MCL for 1,2-dichloroethane in drinking water is 5 μg/L.[93] This level of pollution is of concern not only to the water supply on-site, but also to villages downstream of the industrial complex.

[92] ATSDR, 2001, p. 155.
[93] EPA, 2002.

Table 3: Groundwater pollution at HIP Petrohemija

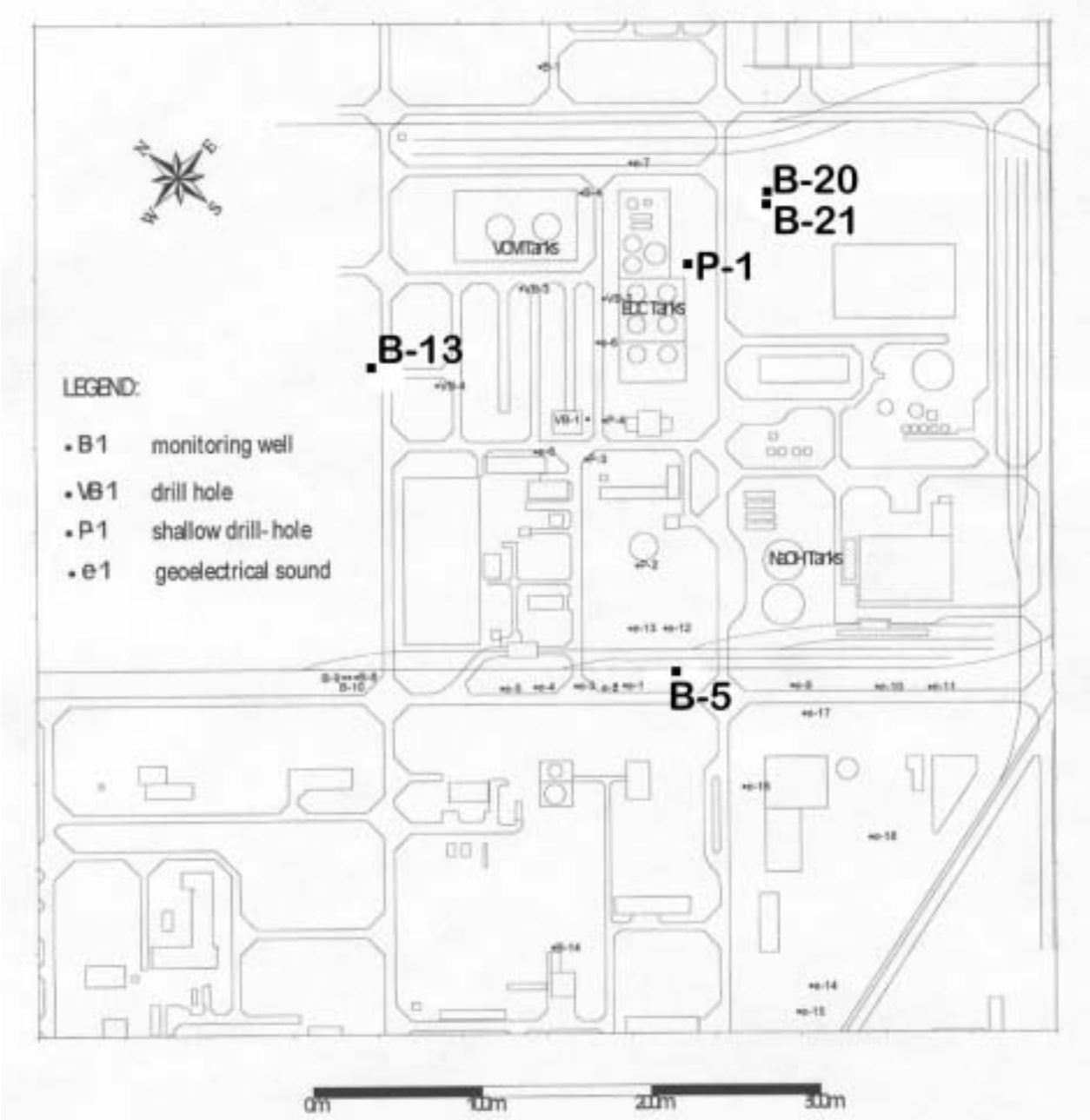
Contaminant	Maximum Concentration (micrograms per liter)	Sampling Point	Depth (meters)	Maximum Contaminant Levels (U.S. EPA) (micrograms per liter)	Factor by which Max. Contaminant Level is Exceeded
1,2-dichloroethane	7,500,000	B-5	18	5	1,500,000
Vinyl chloride	70,000	B-5	18	2	35,000
Dichloromethane	26,500	B-21	10.5	5	5,300
Chloroform	100,000	P-1	1	80	1,250
Tetrachloroethane	40,000	P-1	1	N/A	N/A
1,1-dichloroethylene	5,500	B-20	21	7	790
1,2-cis dichloroethylene	29,200	P-1	1	70	420
1,2-trans dichloroethylene	85,600	P-1	1	100	860
1,1 dichloroethane	95,600	P-1	1	N/A	N/A
Trichloroethylene	16,500	B-21	10.5	5	3,300
Tetra-chloroethylene	374	B-13	7.5	5	75
1,1,2-trichloroethane	48,000	B-20	21	5	9,600
1,1,2,2-tetrachloroethane	2,220	B-13	7.5	N/A	N/A
Chlorobenzene	343	B-20	21	100	3.4

Sources: Dekonta-Aquatest, 2001, Table 2; HSDB Web Site; EPA, 2002.
Note: N/A denotes that there is no established MCL for that particular chemical.

The other contaminants listed in Table 3 are included to provide a more complete picture of the situation at HIP Petrohemija. It is not certain if all of these pollutants were released as a result of the bombings because, as noted in Chapter 1, the area had high pollution levels from organic pollutants prior to the NATO bombings. The measurements at shallow depths are likely reflective of contamination caused by the bombings because the contaminants would not have had time to penetrate deep into the soil. It is not clear why there are so many different pollutants in the immediate vicinity of the 1,2-dichloroethane spills (e.g., the high levels of chloroform and other chlorinated solvents at location P-1), as there are no reports that these compounds were spilled. Possibly, these conditions existed before the bombings. This is likely the case with the vinyl chloride levels that were found in the water because the reports indicate that all of the vinyl chloride in tanks that were hit burned and none of it spilled. Many of these compounds are unwanted by-products of polyvinyl chloride (PVC) production, the major industrial process that occurs in this section of the complex.[94]

[94] Greenpeace, 2001, table 3.

Figure 3: Locations of groundwater sampling wells at HIP Petrohemija



Source: Adapted from Dekonta-Aquatest, 2001, p. 8.

Most significantly, comparison of data measured in 2000 with data previously presented by the BTF, dating to 1999, shows that the contamination plume has spread both vertically and horizontally. No intervention occurred until late 2001. This spread will only continue if urgent action is not taken. In that same survey of 2000, a two-meter

thick layer of free-phase DNAPL was detected 200 meters away from the spill site at sampling locations B-5 and B-6 (see Figure 3).[95] Until it is removed, this free-phase material will be a constant source of pollution to the underground aquifers. That is, the free-phase material will dissolve into the aqueous phase, which in turn can be consumed by people who extract water from the aquifer. Natural processes cannot be depended upon to quickly break down the compounds in highly contaminated groundwater such as this. The biodegradation half-life of 1,2-dichloroethane in groundwater can range from less than one to 30 years depending upon conditions.[96] These conditions include oxygen availability, the biota present, the chemical conditions of the water, the water's pH, and others.[97]

Fortunately, the municipal water supply of Pancevo lies upstream of the industrial site. However there are private irrigation wells downstream of the spill that need to be watched closely. These wells are used to pump water to channels that are used for irrigation of the surrounding agricultural areas.[98] Because of the presence of these wells, the current level of contamination could pose a threat to public health. Attempts were made by the author to gather population statistics in order to determine how many people could be affected by contaminated well water, but they were unsuccessful. There are several villages downstream of the Pancevo industrial site and the city of Smedrevo is approximately 20 kilometers downstream of Pancevo. All of these areas that use well water may be affected in the future if proper cleanup is not undertaken.

In the most recent soil study of HIP Petrohemija, in-situ soil gas surveys were carried out to determine the scope of the soil pollution on-site. A soil gas survey is a technique by which the gas in the vadose zone is removed by vacuum and the collected gas is analyzed for the presence of pollutants.[99] This method is especially effective for determining the presence of volatile organic compounds, because they tend to evaporate easily. As in the groundwater survey, petroleum hydrocarbons often associated with PVC production were found on the Pancevo site. The volatile hydrocarbon concentrations (i.e., the 1,2-dichloroethane) were limited to the area of the initial spill and there was a sharp delineation between the contaminated and uncontaminated zones.[100] The fact that the area of contamination has not really spread 1,2-dichloroethane on the surface indicates that any movement from a surface spill would be downward toward the aquifer. As described earlier, once contamination has reached the aquifer, it spreads horizontally in the direction of the groundwater flow.

Another issue that must be addressed is the 8 metric tons of mercury spilled at the chlor-alkali plant of the complex as a result of the bombings. Seven thousand eight hundred

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[95] Dekonta-Aquatest, 2001, p. 2. The term free-phase refers to the fact that the liquid is not mixed with or dissolved in water. There is an independent layer of 1,2-dichloroethane moving along the bottom of the aquifer.
[96] Biodegradation is the term used to describe the breakdown of chemicals by biological processes.
[97] ATSDR, 2001, pp. 167 to 169.
[98] BTF, 1999a, p. 5; UNEP, 2000, Section 2-Pancevo, p. 2.
[99] The vadose zone is the unsaturated zone lying between the earth's surface and the water table.
[100] Dekonta-Aquatest, 2001, p. 4. The term mg/kg stands for milligrams per kilogram.

kilograms (7.8 metric tons) of mercury spilled in the building and onto the soil surface. Of all the environmental hazards present in Pancevo, the mercury spill is the only one that has received any significant attention until relatively recently. This is due to the fact that mercury is extremely volatile and its vapors can present a serious and immediate threat to people in the area. The FOCUS group led the effort to remove the metallic mercury that was on the ground inside and outside the plant and to excavate the contaminated soil. Unfortunately, these wastes are still in temporary storage, as a permanent waste site has not been established.

All of the liquid mercury within the building and on its grounds was collected by vacuum aspiration. Then the most polluted soils, an area of 1,500 square meters, were excavated to a depth of 1 meter and placed in a lined landfill.[101] Some residual mercury pollution remains in the soil, ranging from less than 10 milligrams of mercury per kilogram of soil (mg/kg, parts per million by weight) of soil to over 100 mg/kg. Exact measurements were not provided and no other document collected for this report makes any mention of this residual mercury pollution. It is also not clear from UNEP's description whether or not this contamination is a direct result of the bombing or if these areas (which total approximately 20,000 square meters of soil) were significantly polluted beforehand.[102] As is described below, strong evidence stemming from sampling in the wastewater channel indicates the area has suffered from significant and chronic mercury pollution. In addition, samples from the dumpsite of Petrohemija reveal mercury contamination as high as 139 mg/kg.[103]

The groundwater in the area also suffers from mercury contamination. Measurements taken by FOCUS soon after the bombings measured mercury concentrations in the groundwater below the chlor-alkali plant from 5 to 900 μg/L.[104] This range exceeds the U.S. EPA standard of 2 μg/L.[105] The UNEP report of its February 2000 mission did not report mercury concentrations below the chlor-alkali plant, but two groundwater samples taken from the vicinity of the vinyl chloride plant tested for mercury concentrations greater than 2 μg/L. Two wells located closest to the vinyl chloride plant showed mercury concentrations of 8 and 87 μg/L.[106] This might further indicate pre-conflict contamination. UNEP has proposed remediation schemes for the areas that are contaminated with mercury and these will be discussed in Chapter 4. A feasibility study and risk assessment for the remediation of this area is on going, but as yet no information about this investigation has been released.[107]

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[101] UNEP, 2000, Section 2-Pancevo, p. 12.
[102] UNEP, 2000, Section 2-Pancevo, p. 13.
[103] UNEP, 2000, Section 2-Pancevo, p. 26.
[104] UNEP, 2000, Section 2-Pancevo, p. 13. According to Dutch law, sites contaminated with mercury exceeding 10 mg/kg require remediation. The German standard for industrial sites is 80 mg/kg. The United States does not have federal soil standards specific to mercury.
[105] EPA, 2002.
[106] UNEP, 2000, Section 2-Pancevo, pp. 5, 24.
[107] UNEP, September 2002, p. 4.

Data quantifying the pre-conflict mercury levels in the water systems around Pancevo are not available. Also, no current data are available regarding mercury contamination of the waste channel or the Danube. The most recent available data comes from the year 2000. Therefore, only inferences can be made about mercury contamination based on data gathered by UNEP and other sources. The mercury contamination caused by the bombings, although serious, compounded an already existing problem. For example, an area of contamination, near the chlor-alkali plant, referred to as the "mercury lagoon," most likely resulted from spills and routine releases that took place before the bombings.[108]

After the bombings in 1999, mercury levels were measured in mussels and they showed a mercury content between 0.15 mg/kg of dry weight (upstream of the canal) and 0.22 mg/kg of dry weight (downstream of the canal).[109] There is no recent data describing the contaminant levels of aquatic organisms. The U.S. EPA's Tissue Residue Criterion for mercury in fish and shellfish is 0.3 mg/kg of dry weight.[110]

Mercury can undergo transformation in; just as it can in ground and surface waters.[111] Transformation is the general name by which an element is changed into a different form via a biological or chemical reaction (e.g., the transformation of mercury into methyl mercury). In anoxic conditions, mercury can be transformed into a sulfide that is less mobile and insoluble. Also, under certain conditions mercury can be mobile in soil and migrate to the groundwater. If more steps are not taken soon, the mercury will spread deeper into the aquifer and further outward, making cleanup much more difficult and expensive. Also, due to its density, mercury sinks to the bottom of the water system. The mercury that was spilled was elemental in form because it was being used in the chlor-alkali process for chlorine production. It can act as a continuous source of pollution as changes in the chemistry of the system cause it to adsorb and desorb from sediment particles.[112]

Finally, over 100 metric tons each of hydrochloric acid and sodium hydroxide were spilled in HIP Petrohemija. These probably presented much more of a short-term threat than a permanent one. Given the lack of data, and the time that has passed since the bombings it would be impossible at this point to quantitatively assess the damage incurred by these spills. The two spills may have neutralized each other, at least partially. The material that was not neutralized would have been removed from the soil via evaporation. Because both of these species are very reactive, their half-lives in the environment are quite short. As a result, the main danger would have been to workers on site as the vapors given off by the spill were probably quite noxious. The salt concentration of the water in the waste channel probably increased, at least in the short term. Today, the 1,2-dichloroethane spill remains the main concern.

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[108] Lozajic, 2002.
[109] BTF, 1999a, p. 41.
[110] EPA, January 2001, p. xvi.
[111] ATSDR, 1999, p. 409.
[112] ATSDR, 1999.

Surface Water Pollution

During the 1999 UNEP mission to Pancevo, 1,2-dichloroethane was detected in the Danube 4 kilometers downstream of the waste channel where the concentration was 0.3 μg/L.[113] More recent data on 1,2-dichloroethane concentrations in the Danube downstream of the spill site is not available. A UNEP survey from February 2000 found free-phase 1,2-dichloroethane in the wastewater channel.[114] Figure 4 shows the results of the analysis undertaken by UNEP during this sampling mission. In May 2000, Dekonta-Aquatest, a joint Czech/Serbian contractor, took two samples from the waste channel and measured for 1,2-dichloroethane content. Free-phase oil was not detected but it may exist in pools at the bottom of the channel or might have already entered the Danube. Measurements of water samples from the canal showed a 1,2-dichloroethane concentration ranging from 464 to 518 μg/L.[115] By comparison, the U.S. EPA standard for this pollutant allows a maximum contaminant level (MCL) of 5 μg/L.[116]

There is also significant mercury contamination in the wastewater channel. The 1999 UNEP sampling mission showed significant contamination in the upper 20 centimeters of the sediment in the wastewater channel with measurements ranging from 15-29 milligrams of mercury per kilogram of sediment (mg/kg). At a depth of 60-80 centimeters, the concentrations increased to 44-49 mg/kg.[117] This level of contamination in the upper levels of sediment demonstrates that while there was contamination in the past, the releases caused by the bombings are significant when compared to past conditions.

Other chemicals were also spilled into the wastewater channel, namely 70 metric tons of 100% hydrochloric acid, and an unknown fraction of 300 metric tons of spilled 50% sodium hydroxide.[118] These spills would most likely have had a short-term effect on the area as they would have undoubtedly affected the acidity of the water. Although they possibly partially neutralized each other, it is unlikely that the ratio was exactly one to two, so the acid content of the water would still have been affected. Fish kills were reported immediately following these spills in the waste channel and in the area where the waste channel meets the Danube. These spills, in conjunction with the major ammonia spill that took place, likely contributed to it.[119] But because natural waterways are buffered systems that are constantly changing, it is doubtful that these altered conditions would have remained for long periods of time.

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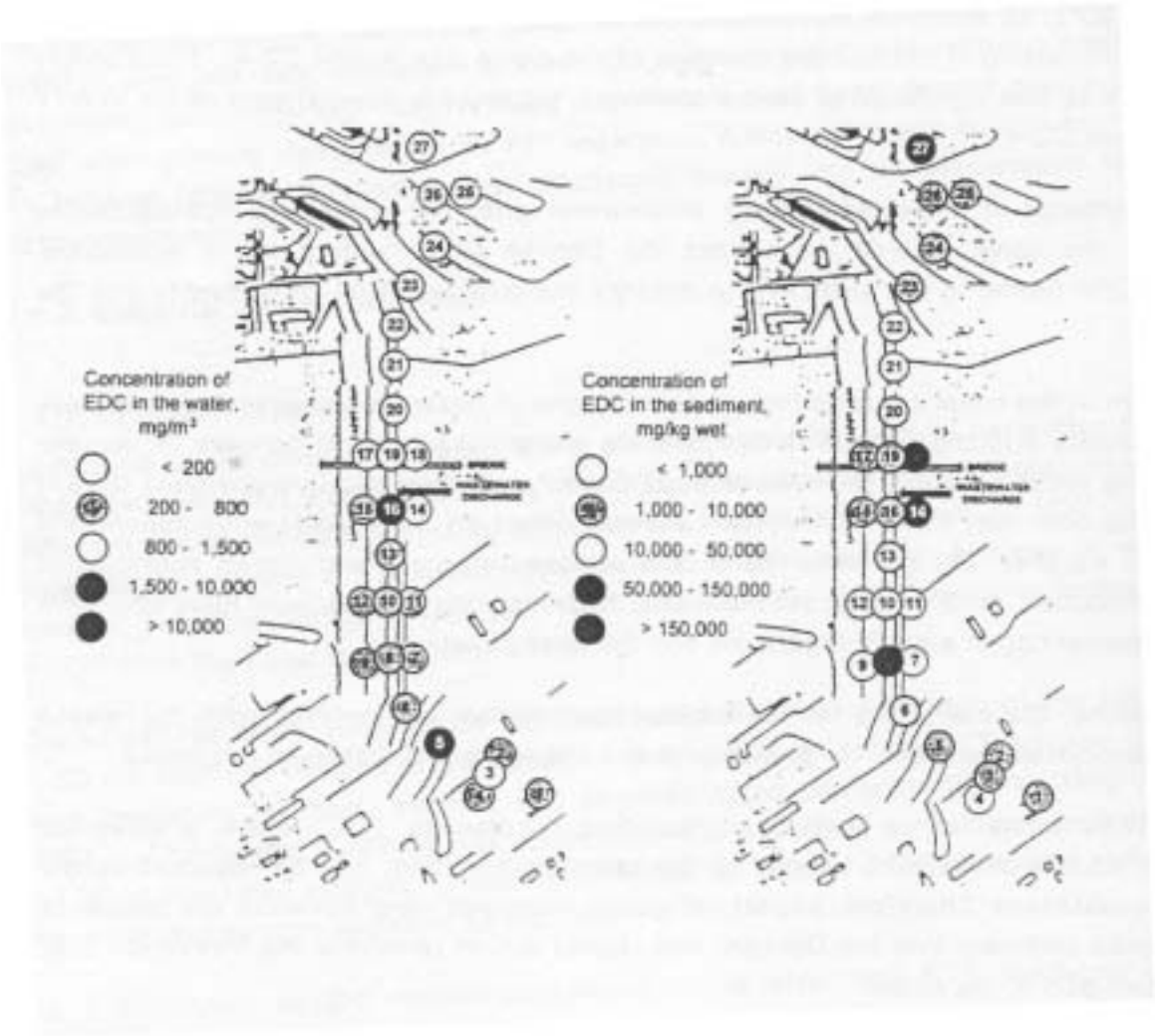
[113] UNEP, 1999, p. 37.
[114] UNEP, 2000, Section 2-Pancevo, p. 50.
[115] Dekonta-Aquatest, 2001, p. 29.
[116] EPA, 2002.
[117] BTF, 1999a, pp. 39, 40.
[118] OMEGAM, 2000, p. 10; BTF, 1999a, p. 11.
[119] BTF, 1999a, p. 23.

Figure 4: 1,2-dichloroethane distribution and concentrations in the Pancevo wastewater canal, February 2000



Source: UNEP, 2000, Section 2-Pancevo, p. 49.
Note: Data is given in milligrams per cubic meter (mg/m^3) of water. 1 mg/m^3 is equal to 1 microgram per liter (μg/L).

The environmental effect of these spills is compounded by the fact that HIP Petrohemija's biological wastewater treatment plant was severely damaged during the bombing. This plant was used to treat waste from both the oil refinery and the petrochemical plant. At full capacity, it was able to handle 1000 cubic meters of waste water every hour. In April, 2001, it was at 20% capacity and was unable to treat the refinery's waste. The refinery waste now only undergoes density separation treatment and then is released directly into the channel. The FOCUS group installed a floating

barrier to help remove some of the excess oil before it reaches the Danube.[120] At the time of the UNEP sampling mission in 1999, petroleum hydrocarbon levels in the wastewater channel were as high as 800 mg/L.[121] The U.S. EPA and World Health Organization have not established regulatory standards for total petroleum hydrocarbons because hundreds of compounds fall under this category. This appears to be the most recent available data regarding petroleum hydrocarbon contamination in the waste channel. Subsequent missions by UNEP have tested for contamination of 1,2-dichloroethane, but no data was published regarding petroleum products. UNEP has begun repairing the treatment system; this process was scheduled for completion by the end of 2002.[122].

NIS Oil Refinery

Groundwater and Soil Pollution

The main threats posed by the results of the bombings at the oil refinery are the oil products that leaked onto the soil surface after storage tanks where hit. Oil products from the surface will act as a constant source of pollution to the groundwater system. Contaminants have already migrated into the aquifers beneath the refinery. Table 4 shows the most recent available water quality data from the aquifer beneath the refinery complex.

Table 4: Groundwater pollution at the NIS Oil Refinery

Contaminant	Maximum Groundwater Concentration (micrograms per liter)	Groundwater Sample Depth (meters)	Maximum Contaminant Levels (water) (U.S. EPA) (micrograms per liter)	Factor by which Max. Contaminant Level is Exceeded
Benzene	9,100	6.3	5	1820
Toluene	4,820	6.3	1,000	4.82
Ethyl benzene	5,330	6.3	700	7.61
Xylenes	11,500	6.3	10,000	1.15
PHCs[1]	109,000	6.3	N/A	N/A
1,2-dichloroethane	66,900	6.3	5	13,380

Source: UNEP, 2000, Section 2-Pancevo, Annex C2-3b; EPA, 2002.

Note:[1]PHC is an abbreviation for Petroleum hydrocarbon. There is no regulatory standard for total petroleum hydrocarbons in the United States.

As expected, the groundwater is heavily polluted with petroleum hydrocarbons.[123] Some petroleum hydrocarbons, such as benzene, are classified as human carcinogens.[124] Lead

[120] FOCUS, part II, pp. 10, 11.
[121] BTF, 1999a, p. 35.
[122] UNEP, September 2002, p. 5.
[123] Benzene, toluene, ethyl benzene, and xylene fall into the category of petroleum hydrocarbons along with more complex chemicals that fall into the PHC category on Table 4.
[124] HSDB web site.

was also detected in the upper soil, most likely because of the spilling/burning of leaded oil gasoline and oil products.[125]

As with the groundwater contamination at HIP Petrohemija, once the pollutants enter the groundwater system they can migrate along with the groundwater and be potentially harmful to downstream populations that depend on groundwater for irrigation or municipal water. This migration potential is illustrated by the presence of 1,2-dichloroethane in the aquifer beneath the refinery. Of note, 1,2-dichloroethane was not stored on the refinery grounds and there is no indication that 1,2-dichloroethane was required in any processes going on at the refinery. As a result, the 1,2-dichloroethane contamination at the refinery is likely a result of the spill at the petrochemical complex from the time of the bombing or some pre-conflict spill.

No data is available to determine the exact levels of pollution that existed in the aquifers beneath the refinery before the bombing. However, surveys conducted prior to the bombings established that there was a oil pollution in the aquifers beneath the industrial complex.[126] Given the shallow depth of the groundwater samples presented here, it is plausible to say that at least some, possibly much, of the contamination shown in Table 4 is the direct result of the bombings.

Not only does the groundwater beneath the refinery need to be cleaned as soon as possible to prevent the further spread of the contamination, but the source of contamination in the soil needs to be removed. The groundwater will continue to be polluted as long as contaminants are able to migrate downward from contaminated soil. Many pipelines and storage tanks were destroyed during the bombings and approximately 5,000 to 7,000 metric tons of oil products were spilled onto the soil surface at the refinery, contaminating about 95,000 square meters of soil.[127] Table 5 lists the soil contamination levels that were present during the UNEP sampling mission of February 2000. Figure 6 shows the areas of the refinery that are contaminated. This is the most recent data that was available for this report.

Table 5: Soil pollution at the NIS Oil Refinery

Contaminant	Maximum Soil Concentration (milligrams per kilogram of soil)	Soil Sample Depth (centimeters)
Benzene	2,230	58-68
Toluene	2,090	58-68
Ethyl Benzene	872	58-68
Xylenes	4,560	58-68
PHCs[1]	3,490	58-68
Lead	95.2	0-10

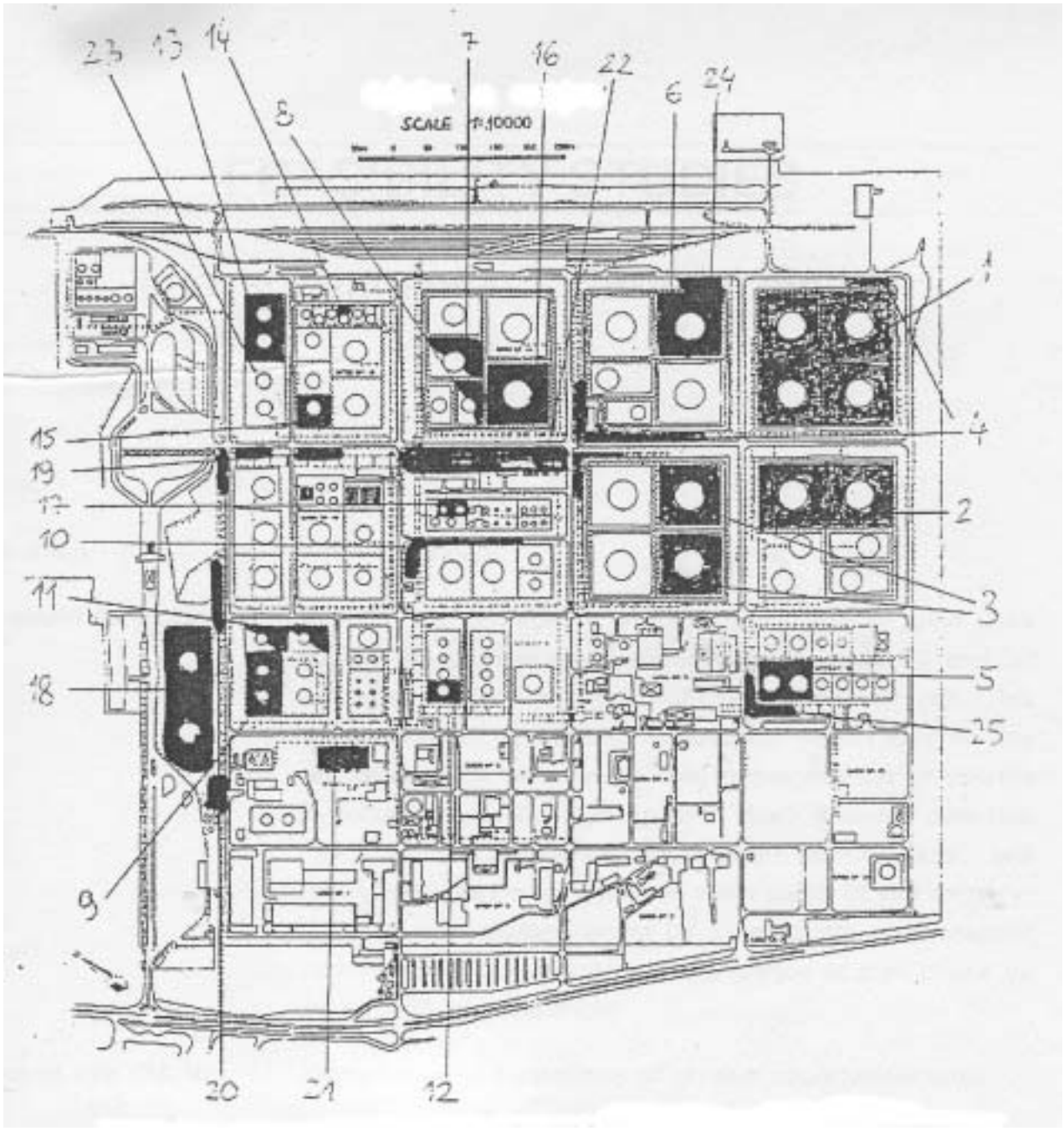
Source: UNEP, 2000, Section 2-Pancevo, Annex C2-3a

Notes: [1]PHC is an abbreviation for Petroleum hydrocarbon

[2]There are no regulatory soil standards in the United States for any of the substances in this table in the United States.

[125] BTF, 1999a, p. 43; UNEP, 2000, Section 2-Pancevo, p. 30.
[126] Jovancicevic, *et al.*, 1997.
[127] UNEP, 2000, Section 2-Pancevo, p. 30.

Figure 5: Contaminated soil at the NIS Oil Refinery



Source: Adapted from UNEP, 2000, Section 3-Feasibility Study, p. 61.

Note: Darkened areas represent contaminated soil.

UNEP classified the 95,000 square meters of contaminated soil into three categories. Priority A areas present an immediate threat to worker health and groundwater contamination because the spills occurred in unlined areas or the spilled material was very mobile. In, Priority B areas, there is a possibility for worker exposure and groundwater contamination, but not to the degree of Priority A areas. Priority C areas present little threat to worker health and little immediate threat to groundwater because the spills took place in areas where there is little activity and/or the material was spilled into lined basins. In UNEP's initial survey of the site, roughly 13,000 square meters (m^2) fell in to the category A, 31,350 m^2 fell into category B and 52,000 m^2 fell into category C.[128] Construction of a 1,700 cubic meter (m^3) concrete basin that will be used for remediation and storage of oil sludge began in September 2001.[129] The main work has been completed and additional works are expected to by complete by the end of 2002.[130]

Oil products are a complex mixture of a variety of compounds. When factored with environmental variables, it becomes almost impossible to accurately predict the behavior of these chemicals. They may undergo bulk migration and simply move together. Or, certain compounds may separate from the rest and migrate alone.[131] This spill may represent a very real danger to the workers at the complex and to the groundwater. Compounds such as benzene and toluene are very mobile in soil and therefore threaten the aquifers beneath. At the same time, they are volatile compounds that evaporate easily and therefore workers can be exposed to them via inhalation.[132]

In addition to the spilled petroleum products, the sewer system and wastewater pre-treatment systems at the oil refinery are in dire need of repair. The system consists of two parts: an approximately 9,300-meter long underground pipe system for the collection and transport of oily waste waters and an approximately 9,400-meter long system of underground pipes and open ditches to deal with storm water runoff. An estimated 2,000 meters of pipelines were destroyed or damaged by the bombings.[133] Wastewater is leaking underground and contaminating the groundwater. The problem only grows as the plant continues to operate while the waste system is damaged. Until this system is repaired, it will act as a permanent source of soil and groundwater pollution. The design process for repairs is on going and construction is scheduled to take place during the fall of 2002.[134]

Surface Water Pollution

Little data is available concerning petroleum pollution in surface waters around the industrial complex. During the 1999 BTF sampling mission, the canal was found to be visibly contaminated with oil. Total hydrocarbon concentrations ranged from 38 milligrams per liter (mg/L) to 800 mg/L.[135] The February 2000 sampling mission did not

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[128] UNEP, 2000, Section 2-Pancevo, pp. 52, 53.
[129] UNEP, December 2001, p. 4.
[130] UNEP, September 2002, p. 5.
[131] ATSDR, 1999b, p. 69.
[132] HSDB web site.
[133] UNEP, 2000, Section 2-Pancevo p. 35.
[134] UNEP, September 2002, p. 5.
[135] BTF, 1999a, p. 35.

assess petroleum hydrocarbon levels in the wastewater canal or the Danube. If such data does exist, it has not been made available to the public.

Surface water is at risk because the wastewater treatment plant that treats waste for both HIP Petrohemija and NIS Oil Refinery was damaged during the bombings. As a result, quantities of oil, perhaps large quantities, were released into the waterways during and immediately after the bombings. Undoubtedly the damage to the treatment plant has led to the increased release of oil based pollutants into surface water systems but this effect cannot be quantified due to the lack of pre-conflict data.

HIP Azotara

Water pollution

The major release at the fertilizer plant that took place as a result of the bombings was the dumping of 250 metric tons of ammonia into the wastewater channel.[136] Because ammonia plays an important role in the nitrogen cycle, it is a short-lived compound in the environment. Therefore, it is doubtful that there will be any permanent effect to the area as a result of this release alone. Ammonia tends to volatilize when added to surface water, so this may have been the fate of a large part of the ammonia that was dumped into the channel. Given the complexity of the system and the large quantity of ammonia, it is not possible to know precisely how much volatilized.[137] Similar results could be expected from the calcium ammonium nitrate and potassium chloride also released into the channel. While these latter compounds could have affected the pH of the water, they most likely would have increased its salt content significantly in the short term. However, there is no data to confirm a change in pH or a change in salt content. This spill along with the others described here probably contributed to fish kills that were observed around the confluence of the Danube River and wastewater channel in the days immediately following the bombing.[138]

C. Air Pollution

With all of the products that were burned over the course of these bombings, toxic materials were certainly released into the atmosphere. In fact, pollutants that correspond to those released by the bombings at Pancevo were detected in trace amounts as far as Xanthi, Greece, some 500 kilometers away.[139] The problem arises in attempting to quantify the amount of each pollutant present in the atmosphere, the nature of its transport, the properties of the pollutant (as combustion changes the chemical composition of the material), and the effect it will have on the surrounding region. The releases to the air from each of the facilities are described below.

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[136] UNEP, 1999, p. 34.
[137] ATSDR, 1990, p. 74.
[138] BTF, 1999a, p. 9.
[139] Vukmirovic, *et al.*, 2000.

HIP Petrohemija

The major airborne releases from the petrochemical factory involved the combustion of 460 metric tons of vinyl chloride and the controlled burning of 1,900 tons of ethylene and propylene. The latter was done under controlled conditions, so presumably the propylene and ethylene was allowed to burn to completion, leaving only carbon dioxide, water, and trace amounts of carbon monoxide as products of the reaction. If proper safety precautions were taken, combustion would not present a health threat to the surrounding communities.

The vinyl chloride tank was bombed on the morning of April 18, 1999. If the vinyl chloride combustion reaction were to go to completion, the main products would be carbon dioxide, water, and hydrochloric acid. The main quantifiable threat in this case is the production of large amounts of hydrochloric acid.[140] If the reaction is assumed to have gone to completion and that one molecule of hydrochloric acid was produced for every molecule of vinyl chloride, approximately 270 tons of hydrochloric acid would have been produced.[141] Anyone who was in the general vicinity of the fire would have been exposed to potentially caustic fumes. The corrosive materials in the plume could have caused respiratory ailments to people in the immediate area, especially those with pre-existing respiratory conditions. It also rained in the days immediately following these bombings. The production of hydrochloric acid could have acidified the rainwater, which may have affected local vegetation.

Under certain conditions, phosgene ($COCl_2$), a chemical warfare agent during World War I, and dioxins could be produced with the combustion of vinyl chloride under certain conditions. However, experiments show that the production of phosgene took place at very high temperatures and it is not clear if those temperatures were reached in Pancevo. Researchers found that "an optimum air/VCM [vinyl chloride monomer] ratio was required for the production of phosgene; ratios above or below this optimum tend to suppress phosgene formation."[142] No such mixing would have taken place in this case because the compound was being stored in sealed tanks. No sources consulted in this report indicate phosgene production as a result of this fire. Even if phosgene were to be produced, it would have been only in trace amounts. Experimental data suggests that the amount of phosgene produced even under optimal conditions is up to three orders of magnitude less than the remaining combustion products.[143]

While these considerations indicate that phosgene may not have been a major problem, the uncertainties in weather patterns at the time, as well as lack of measurements means that it is difficult to conclude definitively that no local residents were affected. All that can be said is that the conditions were not conducive to an adverse outcome due to phosgene and that there has not been any official reporting of phosgene-related problems.

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[140] O'Mara, *et al.*, 1971.
[141] Borelli, 2001.
[142] O'Mara, *et al.*, 1971; pp. 154, 155.
[143] O'Mara, *et al.*, 1971.

It was assumed for the sake of simplicity that the vinyl chloride fire was a combustion reaction that went to completion, meaning it was an ideal reaction and all of the vinyl chloride burned. However, since the fire did not take place in a controlled setting, complete combustion could not have taken place and therefore we must conclude that some amount of vinyl chloride was released. During the four hours the fire lasted, an ambient vinyl chloride concentration in Pancevo ranged from 0.23 to 0.53 milligrams per cubic meter (mg/m^3) (approximately 0.1 to 0.2 parts per million).[144] There is no ambient air standard for vinyl chloride in the United States; therefore, the only basis of comparison is the occupational standard set by the Occupational Safety and Health Administration (OSHA) of 1 part per million for an 8 hour period.[145] No data with respect to vinyl chloride concentrations on-site at the plant during the time of the fire is available.

NIS Oil Refinery

The airborne release of pollutants from the oil refinery is difficult to quantify. One way to estimate these releases would be to compare these fires to previous incidents at other locations. The most recent examples of large-scale oil fires are those that took place during the Persian Gulf War of 1991. During those fires, air samples were analyzed by Laursen *et al*.(1992) in order to determine the emission factors of various chemical species from the fires. Laursen, *et al.*, estimated the amount of a given chemical generated by the combustion of one kilogram of oil.[146] Based on this data, we estimated the types and amounts of chemical species that were released into the atmosphere in Pancevo (see Table 6).

There is a great deal of uncertainty in determining which species constitute the plume. For example, polycyclic aromatic hydrocarbons (PAHs) are produced during the incomplete combustion of fossil fuels. However, attempts made at measuring the emissions of these compounds in Kuwait were unsuccessful and therefore an estimated value was used (see Table 6).[147] In an effort to further understand the nature of the pollutants released during an oil fire, attempts were made at collecting air quality monitoring data from the Tupras Oil Refinery Fire in Izmit, Turkey that was a result of a major earthquake. Unfortunately, the same problems that were encountered in the investigation into Pancevo were present. The data at Izmit either did not exist or were not made available to the public.

The compounds that present the greatest concern during a fire of this type are sulfur dioxide, nitrogen oxides, soot/particulate matter, and polycyclic aromatic hydrocarbons. The nitrogen and sulfur compounds can cause severe short-term health effects, especially

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[144] Bancov, 1999.
[145] HSDB Web site.
[146] Laursen, *et al.*, 1992.
[147] Olsen, *et al.*, 1995. The authors expected to be able to quantify polycyclic aromatic hydrocarbon emissions from the oil fires, but their sampling missions yielded no detectable amounts. They explain this through shortcomings in sampling methods as well as the possibility that soot material may irreversibly bind polycyclic aromatic hydrocarbon compounds.

to those with pre-existing respiratory conditions. These chemicals are also very reactive in the atmosphere and have been implicated in the production of acid rain. Because the NIS refinery fire was a fairly short event, it is doubtful that any long-term acidic effects would be caused in this case. But it is entirely possible that any rain that fell within a short period of time after the bombings may have been more acidic than normal. Some evidence suggests that this was the case; however, no formal investigations were conducted.[148]

Table 6: Emission factors and estimated chemical release from the Pancevo oil fires

Substance	Emission Factor (gram per kilogram of oil burned)[1]	Estimated Release (metric tons)[2]
Particulates (<3.5 μm)	16-20	1,200-1,500
Elemental carbon (soot)	2.8-5.5	210-410
Total organic carbon (aerosol)	4.0-8.0	300-600
Total organic carbon (vapor)	7.1-20.7	500-1,600
Carbon monoxide (CO)	5.1-11.6	380-870
Carbon dioxide (CO_2)	807-829	61,000-62,000
Methane (CH_4)	1.6-2.8	120-210
Sulfur dioxide (SO_2)	16-33	1,200-2,500
Nitrogen oxides (NO_x)	0.49-0.64	37-48
Polycyclic aromatic hydrocarbons	10% of Total Organic Carbon (aerosol)[3]	30-60

Notes: [1]Source of emission factor data is Laursen, *et al.*, 1992. The units for soot, , total organic carbon, and gaseous carbon species are grams of carbon per kilogram of fuel burned. The units for the sulfur and nitrogen compounds are grams of species per kilogram of fuel burned.
[2]Based on estimate of 75,000 metric tons burned. This is the average estimate from the sources used for this report.
[3]This estimated emission factor is used by UNEP (BTF, 1999a, pg. 31).

The 1999 BTF mission to Pancevo included an estimate of ground level concentrations that might have been observed. This data is given in Table 7. UNEP acknowledges that these are order of magnitude estimates. The actual concentrations that might have existed could have been higher, possibly much higher, than those given here. In doing its calculations, the BTF team estimated that the releases from the fires were distributed over 50 hours. They also estimated that the material released in these fires could have been distributed over an area of 10,000 to 100,000 square kilometers.[149] Without detailed meteorological and air quality data, it is impossible to accurately estimate the conditions to which the residents of Pancevo may have been exposed.

[148] Stevanovic, 2001.
[149] BTF, 1999a, p. 33.

Table 7: Estimated ground-level concentrations of selected pollutants from the NIS Oil Refinery fires

Compound	Estimated Emission Intensity (grams per second)	Estimated Wind Velocity (meters per second)	Estimated Cross-sectional area of plume (square kilometers)	Estimated Maximum Concentration (micrograms per cubic meter)	U.S. EPA Air Quality Standards[2] (micrograms per cubic meter)
Sulfur dioxide	9600	3-5	4-8	200-800	365
Nitrogen oxides	2200	3-5	4-8	50-200	100
PAH[1]	220	3-5	4-8	5-20	N/A
Particulates	4800	3-5	4-8	100-400	65

Source: BTF, 1999a, Table 4.5

Notes: [1]PAH is an abbreviation for Polycyclic aromatic hydrocarbon

[2]These are 24-hour averages. The standard given for nitrogen is specific to nitrogen dioxide and it is unclear how the nitrogen oxides would have partitioned in the atmosphere. The standard given for particulates is that of small particulates (less than 2.5 micrometers in diameter. The standard for larger particulates (less than 10 micrometers in diameter) is 150 micrograms per cubic meter. EPA, 2002b.

The release of PAH compounds from the fires could pose a long-term environmental threat to the area. These are very persistent organic compounds that have been shown to be probable carcinogens and can cause respiratory problems at elevated levels.[150] Once released into the air, these pollutants would have been spread over a wide area and most likely return to the ground via dry or wet deposition.[151] As a result, any such compounds produced in the Pancevo fires could affect surrounding vegetation and agriculture in addition to exposing civilians. Once on the soil, PAHs are also able to be resuspended and therefore are again available for inhalation.

Week-long air measurements were taken in Belgrade in June, July, and August of 1999 to measure residual PAH concentrations at Zeleno Brdo (Green Hill) in Belgrade. The total concentrations for all PAH were 8.64 nanograms per cubic meter (ng/m^3) in June, 5.33 ng/m^3 in July, and 7.42 ng/m^3 in August for those specific weeks.[152]

There are no ambient air regulations for polycyclic aromatic hydrocarbons in the United States or Europe because these compounds often exist in complex mixtures and some of the components of these mixtures pose a greater threat than others. The World Health Organization (WHO) has established guidelines for a specific compound, benzo(a)pyrene

[150] ATSDR, 1995, p. 22, 23.
[151] ATSDR, 1995, p. 236.
[152] Vukmirovic, 2001.

based on a cancer risk of one in one million (10^{-6}) and one in one hundred thousand (10^{-5}).[153]

The WHO guidelines are integrated into lifetime cancer risks. The guideline is 0.12 ng/m^3 of benzo(a)pyrene in air for a 1 in 100,000 risk of cancer and 0.012 ng/m^3 for a 1 in 1 million risk of cancer.[154] The measurements given above for Zeleno Brdo are 24 hour averages for the weeks in June, July, and August. The ambient levels did exceed the more stringent WHO guideline for a period of three months. If these levels do not decrease, they could pose a health risk to people in the area.

Because the purpose of this report is to isolate the environmental effects of the bombings, a few clarifications must be made with regard to PAH contamination. First, no data was available regarding background levels of PAH contamination in Belgrade. Therefore, it is impossible to say whether these numbers represent elevated levels compared to those before the bombings. Second, the benzo(a)pyrene numbers only represent one of several compounds that were detected. Each of these compounds has a varying toxicity and associated risk, so concentrations of the remaining compounds could increase the health risk from inhaling PAHs in the area. These measurements were taken 20 kilometers southwest of Pancevo and 80 kilometers southeast of Novi Sad, the sources of the major oil fires. Depending upon how the compounds traveled in the atmosphere, the residual concentrations could have been more or less depending upon the wind direction and distance from the fire. Finally, given that these measurements were taken in the weeks and months after the bombings, the levels may have been higher, possibly much higher, during the time of the fires.

In addition to PAHs, lead and cadmium were released as a result of the fires in Pancevo. Elevated levels of lead were found at the national park, "Deliblatska pescara", a much less polluted area downwind from the fires in Pancevo. This park is a marshy wetland where large numbers of migratory birds stop during the winter. It is thought that the lead and cadmium measured in this park originated from burning leaded oil products in Pancevo. The material was carried in the atmosphere and then deposited down wind of the fires.[155] This further illustrates the effect these fires could have had on a wide area. However, it is also important to note that some of the lead may have been pollution that resulted from pre-conflict industrial processes. Furthermore, it should be noted that the observed cadmium might have come from ordinance that were dropped in the area in addition to the fires.

[153] WHO, 2000, p. 95.
[154] WHO, 2000, p. 95.
[155] Polic, *et al.*, 2000, p. 7.

HIP Azotara

The pollutants that burned at the fertilizer factory were mainly fertilizer and oil products. Fertilizer products, such as calcium ammonium nitrate, phosphates, and potassium chloride, would be expected to break down into oxidized forms of their constituent elements: nitrogen oxides, ammonia, phosphates, and basic elements. The major threat would have been in the hours and days immediately following the bombings when the local population could have inhaled these compounds. Inhalation could have caused irritation to people breathing them, especially in the case of ammonia, or more serious problems to people with pre-existing respiratory problems. This is assuming that a significant portion of the material did burn, but the actual ratio of leaked material to burned material is not known. Because these particular constituents are all naturally occurring compounds and the fire was a short-term event, they are unlikely to present a long-term threat to air quality in the area. No public health data were made available so it is not known if any increase in respiratory ailments was caused by these specific pollutants.

Chapter 3: Bombings and Chemical Release at Kragujevac

The Zastava factory in Kragujevac (city pop. 150,000) was bombed twice, once on April 9 and again on April 12, 1999 and was hit by a total of 12 bombs.[156] The power station, assembly line, paint shop, computer center, and truck plant all sustained heavy damage or were completely destroyed.[157] As a result, production came to a standstill. Total damage to the complex was tallied at 1 billion deutsche marks (about US$ 500 million), according to factory officials.[158] In the year after the bombings, the Milosevic government spent $80 million to restore production to the car factory. The car factory now has a work force of about 4,500. At the beginning of 2001, 28,000 cars and 1,400 trucks were planned to be produced. This is double the number of vehicles produced in 2000, but much less than from the 180,000 vehicles it produced in 1989.[159] The decrease in production can be attributed to several factors that include the break-up of Yugoslavia and the sanctions placed on the country during the Milosevic regime.

A. Polychlorinated Biphenyl (PCB) Release

Transformers at two locations in the Zastava factory, the paint hall and the power station were damaged and PCB oil leaked into adjacent areas. In the paint hall, an area used to paint automobiles after they have been assembled, approximately 1,400 liters (2,150 kilograms) of pyralene oil, a transformer oil containing a mixture of trichlorobenzenes and PCBs, leaked onto the floor and into waste pits containing 6,000 cubic meters of wastewater.[160] The oil in the transformers was determined to be 205 grams of PCB per kilogram of oil (g/kg oil) and 40 grams of trichlorobenzenes per kilogram of oil.[161] The oil also had high levels of dioxin and furans.[162] Fortunately, the oil that was spilled was largely contained within the paint hall and therefore did not present a great threat to the outside environment. The samples from the paint hall that were analyzed during the initial UNEP mission had PCB levels as high as 41 milligrams per kilogram material.[163]

The transformer in the power station was located near a rainwater drain. Therefore, some of the oil likely leaked into the Lepenica River via the sewer system, but it is impossible to say how much.[164] The oil that leaked from the transformer was a mixture of the PCB compounds Aroclor 1254 and Aroclor 1260 (a one to two ratio) with a total PCB content

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[156] According to UNEP reports, the bombings were on April 9 and 12 . (BTF, 1999b, p.1.) According to factory representatives they were on the April 9 and 10. (Nedeljkovic, 2001)
[157] BTF, 1999b, p. 1.
[158] Nedeljkovic, 2001.
[159] Erlanger, 2001.
[160] Nedeljkovic, 2001; UNEP, 2000, Section 3-Kragujevac, p.3; UNEP, February 2001, p. 7. Pyralene is the trade name of the specific PCB mixture that was used in these particular transformers. See UNEP, February 2001, p. 5.
[161] UNEP, 1999b, p. 3. The trichlorobenzenes are added to reduce the viscosity of the mixture.
[162] UNEP, 1999, pp. 40, 41.
[163] BTF, 1999b, p. 11.
[164] BTF, 1999b, p. 4; UNEP, February 2001, p. 6.

of approximately 70 grams per kilogram of oil.[165] Underneath this transformer was a gravel basin designed to contain any oil that may have leaked out of the transformers. However, it appears that this basin was not sufficient, because samples taken from near the transformer and around the rainwater drain contained PCB concentrations as high as 70 grams of PCB per kilogram of sample. This is higher than even the 41 mg/kg that was found in the contaminated areas of the paint hall.[166]

In addition to these two areas directly affected by the bombings there are several drums of contaminated sand in the waste storage area that were taken from the gravel pit beneath the transformer in the power station after the bombings. Many drums of non-bomb related waste, that have not been carefully labeled and whose condition is deteriorating, are also stored here.[167]

B. Contaminated Areas

Paint Hall Floor and Power Station

In the days after the bombing more than 430 workers cleaned up the spilled oil from the floor by removing the excess oil and placing it in waste containers.[168] However, 400-500 square meters of the floor were still contaminated.[169] The Kragujevac Institute for Public Health began a long-term monitoring program in 2001, but the first results will not be available for a couple of years. Factory management and public health officials stated that the cleanup workers were all examined by doctors and given a clean bill of health.[170] However, according to Pekaa Haavisto, then head of the UNEP's Balkan's Task Force, none of the cleanup workers wore hazard suits and some became ill.[171] Organic pollutants such as PCBs are very insidious and any long-term effects to the workers or the general population may not be known for several years.

A project to remove the contaminated concrete in the paint hall, replace it with a new layer, and cover it with epoxy and anti-static material began in December 2001 under the auspices of UNEP. The project was substantially completed by April 2002 and is expected to be fully completed in summer 2002.[172] Official UNEP documents do not differentiate between the contaminated concrete in the paint hall and the contamination in the transformer station. Presumably both areas are included in the cleanup.

In its initial assessment of the environmental hazards at the Zastava factory, the UNEP team concluded that "large parts of the drain and drain system" around the power station

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[165] BTF, 1999b, p. 11. Aroclor is a trademark name of a specific PCB compound. See UNEP, February 2001, p. 5.
[166] BTF, 1999b, p. 11.
[167] UNEP, February 2001, pp. 8, 9.
[168] Nedeljkovic, 2001.
[169] BTF, 1999b, p. 3.
[170] Nedeljkovic, 2001.
[171] Haavisto, 1999.
[172] UNEP, July 2002, p. 5.

"might be contaminated" and that events such as a large flow of rainwater would likely remobilize the PCBs.[173] However, despite this conclusion, no subsequent UNEP report has dealt with this issue of a contaminated drainage system. If no cleanup is done, the drainage system could pose an environmental hazard.

Wastewater Pit

After initial reconstruction efforts and the reopening of the paint hall, a cover was built over the pit to minimize inhalation exposure to workers and it remained in place until clean-up operations began in early 2002. Samples taken in the pit ranged between 67 and 704 micrograms of PCB per liter of water (μg/L).[174] The U.S. EPA maximum contaminant level for non-transient, non-community water systems is 0.5 μg/L.[175] Decontamination of this water was carried out by UNEP in conjunction with Zastava and institutions from the city government. Work began on this project in August 2001. A system (described in further detail Chapter 4) was constructed to decontaminate the water and the contaminated sludge that remained in the pits was removed. A Certificate of Final completion for this project was issued in April 2002.[176]

Waste Storage Area

The remediation of this area is linked with the other projects around the Zastava factory. Packing of the waste generated by the clean-up process, in addition to the waste already present, is complete. Transport to treatment facilities outside of Yugoslavia and the ultimate disposal of the waste was expected to started in July 2002 with the waste being transported to Switzerland and the damaged transformers being transported to Germany.[177]

Waterways

In the three days after the bombings, the Institute for Public Health took 21 water samples around Kragujevac. Toxics were found on the first and second days, but none were found on the third day.[178] These data were not made available and it is impossible to know what specific toxins were analyzed. People in the area are worried about possible contamination because some wells in the area were not tested for PCB contamination. There is no evidence to suggest that there was any direct input of PCB into the groundwater pathway. However, flooding that occurred during July of 1999 may have spread any pollutants in the waterways to surrounding low-lying agricultural areas.[179]

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[173] UNEP, February 2001, p. 7.
[174] UNEP, 2000, Section 3-Kragujevac, p. 4. These samples were not taken by UNEP.
[175] ATSDR, 2000, p. 619.
[176] UNEP, July 2002, p. 6.
[177] UNEP, July 2002, p. 6; Lozajic, 2002b.
[178] Vasilovic, 2001.
[179] UNEP, 2000, Section 3-Kragujevac, p. 17.

UNEP found levels of PCB in the Lepenica River at 52 micrograms per kilogram (μg/kg) in the sediment at the confluence of the Lepenica and Morava Rivers as well as a 2,400 μg/kg sediment sample taken 4 kilometers downstream of the plant. UNEP claims that this pollution did not come from the bombings, but it is apparent after interviews with factory officials that they feel otherwise. UNEP's claim is based on the fact that the "fingerprint," or chemical composition of the PCB found in the river did not match that of samples taken from the car factory. The PCBs found in the water were less chlorinated and more soluble PCBs than those found at the facility.[180] Without any data from the public health institute of Kragujevac to show otherwise, it is impossible to determine if there are any errors in the sampling of UNEP. However, the opinions of factory and public health officials should not be disregarded. Water monitoring is now under the auspices of the city Hydrometeorological Institute, but as yet no data has been made public.

As a result of a decade of conflicts, lack of openness, economic recession, and other problems in post-war Yugoslavia, it is difficult to make reliable conclusions about the environmental conditions in Kragujevac. Fortunately, the contaminated areas within the factory have been dealt with as these areas presented the greatest threat to worker health. Inhalation is a major pathway of PCB exposure in occupational settings.[181] As a result, the cleaning of the waste pits and the removal of contaminated concrete greatly reduces the amount of worker exposure.

Given the numerous uncertainties and a general lack of data as to how much pollution was released into the environment surrounding the Zastava plant, it is impossible to arrive at any conclusion other than to say that a comprehensive sampling and monitoring mission is urgently needed.

[180] BTF, 1999b, p. 4, 5.
[181] HSDB Web site; ATSDR, 2000, pp. 566-568.

Chapter 4: Public Health and Cleanup Issues

Life in Pancevo and Kragujevac was severely disrupted as a result of the 1999 NATO bombings. Beyond the economic damage that resulted from destroyed property and employment centers, there is no question that a number of toxic chemicals were released to the environment as a result of the bombings. This raises important public health and environmental issues about the effect of precision bombing non-combatants as well as the effects on the environment, notably soil and water, and therefore on future generations. Discussion in this section will not include all of the releases that occurred in these facilities. Instead, the analysis will focus on those problems which, even in the context of a partial and incomplete evaluation, represent a major threat in terms of the scale of the release and in terms of the time over which the pollution will pose a hazard.

A. HIP Petrohemija

1,2-dichloroethane spill

The situation regarding the levels of contamination with 1,2-dichloroethane was described in Chapter 2 in as much detail as possible given the amount of data made available. This portion of the report will examine the threats the spill may pose to the public and the environment and then describe clean-up methods that are being proposed for the area.

The U.S. EPA regulations stipulate that concentrations of 1,2-dichloroethane in drinking water should not exceed 5 micrograms per liter (μg/L, or 5 parts per billion by weight). Concentrations in the groundwater around Pancevo are, in some cases, several thousand times above this limit. This problem will likely worsen because approximately half of the 2,100 metric tons that spilled was released onto the soil surface. Since 1,2-dichloroethane is very mobile in soil, it can be expected to migrate quickly through the vadose zone.[182] Once 1,2-dichloroethane is in the groundwater, it can present a long-term threat. The half-life of 1,2-dichloroethane can vary a great deal, perhaps as long as 30 years in groundwater, depending upon the organisms present, the amount of organic matter in the soil, and other variables.[183]

The remainder of the 1,2-dichloroethane spilled into the waste channel. The primary natural removal processes of this compound in surface water are biodegradation--with a removal half-life ranging from 100 to 400 days--and evaporation, with a removal half-life of 10 days in a lake and probably less in moving systems.[184] However, given the fact that so much material was spilled, and that it is a DNAPL (dense non-aqueous phase liquid) that sinks and can form pools on the sediment, evaporation cannot be expected to remove

[182] HSDB web site; ATSDR, 2001, p. 167.
[183] ATSDR, 2001, p. 169.
[184] ATSDR, 2001, pp. 167, 169; HSDB web site

the pollutant completely. Therefore, 1,2-dichloroethane is likely to pose a long-term threat unless it is cleaned up.

1,2-dichloroethane has been shown to be carcinogenic in animal studies and is classified as a possible human carcinogen.[185] Each of the pathways--groundwater, soil and surface water--represents a way for the public to be exposed to unnecessary levels of 1,2-dichloroethane. Private wells downstream of the industrial site are used for drinking water. Also, because the soil was saturated with 1,2-dichloroethane from the spill, workers could have been exposed to vapors resulting from the volatilization of the chemical. No data is available regarding ambient air concentrations of 1,2-dichloroethane on the facility site, so it cannot be determined if evaporation and leaching took place quickly enough to disregard this exposure pathway. Finally, people in the area continue to eat fish from the Danube River. Fortunately, 1,2-dichloroethane does not seem to be retained by fish and therefore it does not appear to bioaccumulate up the food chain. However, if fish could ingest 1,2-dichloroethane and be eaten before the it was excreted. Fish could, therefore, serve as a carrier of this pollutant.

Several remediation methods are being proposed for Pancevo and one is already in use to clean up the 1,2-dichloroethane contamination. These include steam-enhanced extraction, pump and treat, soil vapor extraction, and natural attenuation. A fifth, less desirable, approach to soil clean-up might be to simply remove the contaminated soil (if it is a manageable amount) and place it in temporary storage until a suitable method of treatment or disposal can be found. Steam-enhanced extraction involves the injection of steam into the contaminated part of the aquifer. The heat volatilizes and mobilizes the contaminant at which point the condensed steam and the contaminant are collected at extraction wells.[186] The advantages of this method are that it is quick and can be very effective. The disadvantage is that it might mobilize the contaminant and cause it to spread at an even faster rate.

A pump and treat system involves physically removing the water from the aquifer, treating it to remove the contaminants (this can be done in a variety of ways) and then re-injecting the water into the aquifer. The main benefit of this method is that it is very thorough. The major drawback is that the cost and time involved increase with the amount of water that must be treated. This method is currently being used at HIP Petrohemija to treat areas that are in urgent need of remediation.[187]

Soil vapor extraction is used to clean a contaminated soil surface. A flow of air (usually a vacuum) is induced through the soil surface, which causes the movement of the volatile compounds to move towards a well that is as deep as the contaminated soil. The vapors, and therefore the contaminants, are extracted from the well. This method is often combined with air sparging. The two techniques are very similar with the exception that

[185] ATSDR, 2001, pp. 84, 196.
[186] NAS, 1999b, p. 163.
[187] UNEP, July 2002, p. 5.

the term "air sparging" is often specifically used in relation to groundwater clean-up.[188] This method of clean-up is very effective; however, it can be quite expensive.

Finally, the cheapest method of clean-up is natural attenuation. In this case, natural processes (i.e. biodegradation, volatilization) clean the contaminated areas without intervention. This can be an acceptable strategy when there is not a lot of pollution or when the contaminants are short-lived. However, given the massive contamination, natural attenuation is not a sufficient strategy for clean-up in Pancevo. Contaminated areas should be cleaned to a substantial extent before natural attenuation is relied on to take over. Unfortunately, natural attenuation has been the default method of clean-up in Pancevo for over two years. As a result, the area is still heavily polluted with 1,2-dichloroethane.

Active remediation of the 1,2-dichloroethane-contaminated areas began in the fall of 2001. Extraction well drilling and waste characterization were completed in November, 2001 and the groundwater that requires urgent remediation is being treated using a pump and treat method. Evaluation of further remediation techniques was completed in the summer of 2002. The main portion of the 1,2-dichloroethane remediation is scheduled to begin after this process is completed. This will most likely be in the fall of 2002.[189]

Mercury Spill

Eight metric tons of mercury were spilled at HIP Petrohemija, 200 kilograms were spilled into the waste channel while the remainder was spilled on the soil surface. Because of the very toxic nature of mercury, this is the only problem that received immediate attention in Pancevo.

Mercury can behave in a variety of ways in water. At lower pH levels (acidic environments) mercury binds strongly to organic material, and therefore sorbs strongly to sediment. However, at higher pH levels, the mercury can desorb from the sediment and be transported by the water.[190] If a water system undergoes seasonal changes, for example in pH or organic content, the chemistry of the system can change and affect the mobility of mercury. In soils, metallic mercury tends to form complexes with ions. The specific compounds that are formed depends on conditions such as pH, salt content, and the composition of the soil.[191]

Of even greater concern than elemental mercury is the biotransformation of elemental mercury into methylmercury, because methylmercury can bioaccumulate. Microbial activity can change inorganic mercury into methylmercury, which is carcinogenic, soluble, very mobile, and bioaccumulates in fish.[192] The concentrations of methylmercury in higher order fish can be magnified 10,000 to 100,000 times compared

[188] NAS, 1999b, pp. 140 to 147.
[189] UNEP, July 2002, p. 5; UNEP, September 2002, p. 5.
[190] ATSDR, 1999a, p. 400.
[191] ATSDR, 1999a, p. 409.
[192] NRC, 2000, p. 12; ATSDR, 1999a, p. 406.

to ambient levels.[193] The specific water conditions at the time of the bombings in and around the waste channel are not known. Significant methylation of mercury has not been found to occur *in vivo* in humans.[194] Therefore the only way methyl mercury can enter the body is if it is consumed from an outside source. If sulfides are present and the pH is favorable, mercuric sulfide, which is insoluble, is formed and has not been found to bioaccumulate.[195]

In the HIP Petrohemija facility, the Swiss-based FOCUS group removed the most heavily contaminated soil from the area and placed it in lined storage. Because mercury is a toxic and volatile element it would have posed a serious threat to workers on-site had it been left in the soil. Despite the FOCUS clean-up, significant residual mercury contamination remains at HIP Petrohemija. In 2000, UNEP put forth several options for how cleanup of these areas could progress.[196] All of the options involve the initial excavation of the contaminated soil. Unfortunately, the next steps are more complicated because Yugoslavia does not possess even the facilities required to store the material for long periods of time, much less the technology to extract mercury from the soil.

One option, and probably the cheapest, would be to construct a large landfill near the complex where the excavated soil could be stored until a final treatment is determined. Alternatively, the excavated soil could be transported to another location where it could be stored in a facility designed for the long-term storage or treatment of toxic waste. This option would be very expensive because transportation costs alone would be substantial. Another option is to excavate and chemically treat the contaminated soil, either by stabilization or soil washing. This is the approach that was originally recommended by FOCUS in their initial assessment of the situation.[197]

Stabilization is a process by which mercury is made first into an insoluble, non-volatile compound, through chemical reactions, which then can be disposed of properly without it entering the gaseous phase or leaching through the soil. For example, treatment of the soil with calcium polysulphide or sulfur would generate mercury sulfides that would be completely insoluble and non-volatile. These could then be filtered from the soil and safely disposed.[198]

Soil washing is an *ex situ* process by which the mercury is extracted from the soil using an extraction solution, or mobilizing agent such as acids or chelating agents are.[199] The disadvantage of this method is that it is ineffective in certain types of soil, such as silt and clay. However, it does convert the waste into a liquid form, which can be more treatable than a solid one.[200]

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[193] ATSDR, 1999, p. 401.
[194] Barregard, *et al.*, 1994.
[195] ATSDR, 1999, p. 408.
[196] UNEP, 2000, Section 2-Pancevo, pp. 14, 15.
[197] FOCUS, 1999 Part II, p. 6.
[198] NAS, 1999b, p. 101; FOCUS, 1999, Part II, p. 6.
[199] A chelating agent is a compound that binds metal ions.
[200] NAS, 1999b, pp. 114-116.

These two methods, stabilization and soil washing, would increase equipment costs because Yugoslavia would need to purchase the apparatus to carry out the treatment. At the same time, transportation costs would not be a factor and a major landfill would not have to be built, although some sort of storage would be required because the mercury would still have to be permanently disposed. If other options are chosen, the material would have to be transported because the necessary facilities are not be available on-site.

A feasibility study and risk assessment of the mercury contamination are on-going as is an evaluation of possible remediation techniques.[201] Attempts to obtain the monitoring data that has been taken, mostly by the Swiss Agency for Development and Cooperation (SDC) have been unsuccessful. However, it appears that the mercury contamination may be far more pervasive than previously thought.[202] Furthermore, it appears as though pre-existing mercury contamination may present more of a risk to worker health than the spill that occurred during the bombings.[203] However, this should not minimize the impacts of the spill that took place during the bombings. This new information illustrates what many had come to believe: that the bombings aggravated a pre-existing problems on the Pancevo site.

Vinyl Chloride Fire

Approximately 460 metric tons of vinyl chloride burned at HIP Petrohemija. The major concern would have been the approximately 270 metric tons of hydrochloric acid released in vapor form. Hydrochloric acid fumes are extremely corrosive and cause eye, skin, and throat discomfort at a concentration of as little as 5 parts per million. Concentrations of 50 to 100 parts per million are tolerable for up to one hour and concentrations on the order of 1,000 parts per million are dangerous for even brief exposures.[204] Exposures at the high end of the spectrum could lead to acid burns of the eyes, skin, and respiratory tract. No data that show the hydrochloric acid concentration in the vicinity of the fire, or even on the presence of factory and/or emergency workers are available. From a public health standpoint, the hydrochloric acid fumes may have been at damaging levels at some distance from the actual source. Members of the population who are susceptible to respiratory problems could have been put at risk because the caustic fumes may have exacerbated their problems. Hydrochloric acid is a strong acid and therefore a highly reactive species. It is unlikely that it would suspend in the atmosphere for long periods of time in that form. If it rained in the area at the time when the plume was still spreading, it may have acidified the precipitation.

All accounts indicate that almost all of the vinyl chloride in the tank burned. However, the fact that vinyl chloride was detected in the air in Pancevo shows that at least a small amount of vinyl chloride was released into the environment. Vinyl chloride is a

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[201] UNEP, July 2002, p. 5.
[202] Lozajic, 2002.
[203] Lozajic, 2002.
[204] HSDB Web Site

confirmed human carcinogen and is commonly associated with hepatic angiosarcoma, a cancer of the liver.[205] Most of the data that deals with vinyl chloride carcinogeneity comes from studies involving people who are exposed to it on an occupational and chronic basis at concentrations several times higher than concentrations found in Pancevo (0.1 to 0.2 parts per million). Because vinyl chloride tends to target the liver, people with liver disorders or young children whose organs are still developing may have been particularly affected. The overall effects of the vinyl chloride fire on public health are difficult to assess. The exposure to vinyl chloride in the case of the Pancevo releases would have been relatively short, because vinyl chloride is broken down by hydroxyl radicals in the atmosphere and is expected to have a half-life ranging from a few hours to a couple of days.[206] Yet sensitive parts of the population may have experienced, or may experience, in the future, adverse effects. However, due to the enormous uncertainties involved, it would be difficult to definitively attribute adverse health outcomes to the exposure during the bombing campaign.

If any gaseous vinyl chloride returned to the ground via rain or some other process, it potentially could leach through the soil. However, because of its volatility, most of the compound would re-enter the gaseous phase. The vinyl chloride that remained in the soil could also be biodegraded by microorganisms on the soil surface.[207] Again, no quantitative assessment is possible because of the lack of data and the many uncertainties with analyzing wartime situations.

B. NIS Oil Refinery

Oil Spills

The oil spills in Pancevo present a threat to the public in two ways. First, the threat to workers who might inhale the vapors of the spilled oil products. Second, the oil products are moving through the vadose zone into the groundwater. This threatens agricultural land and people downstream that use groundwater for irrigation and drinking water. Chronic exposure to these petroleum products could lead to a variety of health problems, including respiratory disorders, liver disorders, kidney disorders, and cancer depending upon the specific compounds a person is exposed to and the length of exposure. Cleanup must be done quickly if these unnecessary consequences are to be minimized, or prevented.

The plans set forth for soil remediation at the oil refinery are different than those of the petrochemical complex. In the UNEP proposal, the first step would be to excavate the contaminated soil, after which most of the soil (at least 90%) would be treated microbiologically.[208] The soil would be composted in biopiles where microbial degradation would be enhanced by aerating the soil and/or adding the necessary nutrients

[205] ATSDR, 1997a, p. 54, 55.
[206] HSDB Web Site, ATSDR, 1997a, p. 161.
[207] ATSDR, 1997a, p. 163.
[208] UNEP, 2000, Section 2-Pancevo, p. 34.

to increase microbial activity. Biopiles have been shown to be up to 95% effective in removing hydrocarbons from contaminated soil.[209] In cases of chronic contamination, the local bacterial community is often adapted to feed on the contamination products.[210] The technique involves blending the soil and introducing conditions (such as nutrient level, moisture level, etc.) so that the already present microbes will degrade the pollutants. The advantages of this technique are that it is extremely economical and simple to design, and can be done under closed conditions in which vapor exposure is minimized. The disadvantages are that a significant portion of the refinery would have to be designated to this process. Volatile constituents tend to evaporate rather than degrade, and in some cases the soil would be too polluted for this technique.. The remaining soil could then be incinerated or remediated in some other way.

In addition to the contaminated soil, the contaminated groundwater underneath the refinery also needs to be cleaned. The techniques for remediating the contaminated groundwater are similar to those described for the 1,2-dichloroethane groundwater cleanup process.

Cleanup work began at the NIS Oil Refinery in late 2001. The construction of a concrete basin for clean-up activities is largely complete. Design work on the pipeline system and water treatment unit has begun and construction is to begin in the fall of 2002.[211]

Oil Fires

The fires at the NIS Oil refinery probably resulted in significant releases of sulfur dioxide (SO_2) and nitrates (NO_x).[212] These two compounds are associated with acid rain that results from industrial activities. Although no official data are available, informal experiments were conducted by a scientist, Vladimir Stevanovic, in Belgrade showing that rain that fell in the days immediately after the bombings was more acidic than usual. Acid rain can negatively affect the health of the plants. The effect of acid rain on the vegetation around the area was found to be short-term because the lack of industrial activities in the months after the bombing allowed the surrounding environment to recover. The greenery around Pancevo started turning brown in the weeks after the bombings but then showed significant recovery in the year afterwards.[213] As a precaution, a recommendation was made the Public Health Institute of Pancevo that the people of Pancevo avoid eating leafy vegetables that were grown in the region because they may have been contaminated.[214]

Other volatile organic compounds were probably released during the oil fires. Unfortunately, no data are available to estimate what people might have been exposed to or even what compounds have been released. Estimates of polycyclic aromatic hydrocarbon (PAH) exposure, as well as residual contamination that still exists, were

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[209] EPA, 2002c.
[210] Jorgensen, 2002.
[211] UNEP, July 2002, p. 5; UNEP, September 2002, p. 5.
[212] BTF, 1999a, p. 32.
[213] Stevanovic, 2001.
[214] Bancov, 1999.

described in Chapter 2. Unfortunately, cleanup of the PAH contamination is not feasible because such a large area is affected. The only course of action is to identify those heavily contaminated areas and issue public health warnings to affected populations.

Other Cleanup Issues

In March 2001, two years after the bombing campaign started, the Swiss Agency for Development and Cooperation (SDC) began work on the construction and implementation of an upgraded monitoring system for the entire Pancevo area. Sampling has begun and initial results have been obtained. Attempts to gain access to the monitoring data were unsuccessful.

Work also began on the remediation of the wastewater channel. Contaminants that settled on the sediment will act as a continuous source of pollution to the Danube until they are removed. Surveys of the area were completed in 2001 and the method and design of the cleanup were scheduled to begin in January 2002.[215]

C. Kragujevac

PCBs

After a PCB spill, the most likely routes of exposure are inhalation and water pathways.[216] PCBs are classified as carcinogens and mounting evidence suggests they may act as endocrine disrupters in human beings and of animals.[217] Disruption of the endocrine system can cause a number of problems, including disruption of sexual differentiation and of sexual organ development in fetuses. The contamination contained within the building may have presented a threat to workers because some PCBs are volatile and can be inhaled.

The PCB that leaked into the environment may also present a danger. In water, PCBs tend to sorb strongly to organic matter and are very persistent. But like mercury, changes in the water's chemistry or disruption to the sediment can resuspend the PCBs, at which point they can spread further. Also like organic mercury compounds, PCBs bioaccumulate in the fatty tissues of fish, thus presenting another source of exposure to the local population.[218]

The river system is contaminated with PCBs but the PCB contamination is probably not a result of the bombing. PCBs tend to settle on the riverbed, so the only way to eliminate the problem would be to dredge the riverbed and treat the contaminated sediment. One large-scale example of dredging is the U.S. EPA's ruling requiring General Electric to

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[215] UNEP, July 2002, p. 5.
[216] Eschenroeder, *et al.*, 1986
[217] ATSDR , 2000, pp. 251, 372; Colborn, 1998; NAS, 1999a, p. 38.
[218] HSDB Web Site

dredge and clean 40 miles of the Hudson River in New York state. Over 68,000 kilograms (150,000 pounds) of PCBs are thought to be have been deposited in the river. The projected cost of the cleanup is U.S. $460 million.[219]

The cleanup of the Zastava factory itself is largely complete. The removal of contaminated concrete is mostly complete and was expected to be finished in the summer of 2002. Cleaning of the wastewater pits is complete and a Certificate of Final Completion was issued in April 2002. Transport of hazardous waste to facilities abroad has commenced.[220]

None of the recent UNEP reports address the issue of monitoring the waterways around Kragujevac. The City of Kragujevac started a monitoring program, however no data have been made public. Monitoring does not appear to be getting the attention in Kragujevac that it is getting in Pancevo. This may be because the release of PCBs to the river systems does not seem to be largely a result of the bombings.

[219] EPA, December 2000; EPA, February 2002.
[220] UNEP, July 2002, pp. 5, 6; Lozajic, 2002b.

Chapter 5: Legal Issues

The data and analysis that we have given in these case studies show that precision targeting, even when it works as intended, can result in widespread damage to the environment, imperiling health of present and future generations of humans as well as other life forms. Based on our analysis, we will now consider the legal ramifications of using precision bombing to destroy facilities in ways that result in long-term environmental damage and health risks. This analysis is based on international humanitarian law.

While the primary questions relating to the NATO bombing are whether NATO had authority to use force against Yugoslavia and whether the bombings complied with international law, it is also noteworthy that members of the U.S. government challenged U.S. participation in the campaign. The U.S. role is of particular significance because the United States led the campaign and executed the majority of bombings.[221] On April 28, 1999, by a vote of 213-213, the U.S. House of Representatives rejected a resolution, which had been passed by the Senate, to authorize U.S. participation in the bombing campaign. Thirty-one members of Congress brought a lawsuit against the executive branch, but this case was dismissed from federal court on the grounds that the actions of the House of Representatives were internally inconsistent. Four apparently incompatible votes took place on that day. Specifically, the U.S. House of Representatives voted against U.S. participation in the air campaign, against withdrawing from the conflict, against declaring war, and in favor of demanding congressional approval before ground forces were to be used.[222]

A. International Law

The Authority for NATO's use of force

This section reviews the legal authority for NATO's use of force in Yugoslavia. The principal international legal agreement addressing peace and security is the United Nations (UN) Charter. Article I, paragraph 1 of the Charter states that one of purposes of the UN is:

> To maintain international peace and security, and to that end: to take effective collective measures for the prevention and removal of threats to the peace, and for the suppression of acts of aggression or other breaches of the peace, and to bring about by peaceful means, and in conformity with the principles of justice and international law, adjustment or

[221] The United States committed over 700 of the 1055 aircraft used in Operation Allied Force and U.S. aircraft flew more than 29,000 of the 38,000 sorties flown during the campaign. However, it is impossible to say whether it was U.S. aircraft that bombed the facilities in Pancevo and Kragujevac because this information is classified. See Peters, *et al*, 2000, pp. 23 to 36.
[222] CNN, 1999b.

> settlement of international disputes or situations which might lead to a breach of the peace.[223]

The "suppression of acts of aggression" referred to in Article 1 is primarily the responsibility of the Security Council. Pursuant to Article 24, paragraph 1, the Security Council has "primary responsibility for the maintenance of international peace and security."[224] Chapter VII then describes what actions the Security Council may take with respect to acts of aggression. Chapter VII, Article 39 states, "The Security Council shall determine the existence of any. . .act of aggression and shall. . .decide what measures shall be taken…to maintain or restore international security."[225]

Thus, the UN Charter confers on the Security Council the authority to determine whether force may be used to address conflicts and acts of aggression. The UN Charter also requires that regional organizations, such as NATO, must not use force without Security Council authorization. Article 53, paragraph 1 states that "no enforcement action shall be taken under regional arrangements or by regional agencies without the authorization of the Security Council."[226]

NATO, a defensive alliance formed in part to "develop…individual and collective capacity to resist armed attack," recognizes the legal requirements of the UN with respect to the use of force.[227] Article 1 of the North Atlantic Treaty, the NATO charter, states that members of NATO should "refrain in their international relations from the threat or use of force in any matter inconsistent with the purposes of the United Nations."[228] Article 7 further states that the treaty does not affect "the primary responsibility of the Security Council for the maintenance of international peace and security."[229]

The 1999 air campaign over Yugoslavia was the second offensive action taken by NATO; the Security Council did not authorize it.[230] Prior to the NATO action, the Security Council had adopted resolutions under its Chapter VII authority in response to the Kosovo crisis, but never explicitly called for the use of force. In March 1998, the Security Council called for a political solution to the Kosovo crisis and imposed an arms embargo for both sides.[231] In September 1998, the Security Council determined that the deterioration of the situation in Kosovo constituted "a threat to peace and security in the region," called on Yugoslavia to take certain measures to solve the crisis, and "[d]ecide[d], should the concrete measures demanded in this resolution and resolution 1160 (1998) not be taken, to consider further action and additional measures to maintain

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[223] UN Charter, 1945, Chapter I, Article 1, paragraph 1.
[224] UN Charter, 1945, Chapter V Article 24, paragraph 1.
[225] UN Charter, 1945, Article 39.
[226] UN Charter, 1945, Article 53.
[227] NATO, 1949, Article 3.
[228] NATO, 1949, Article 1.
[229] NATO, 1949, Article 7.
[230] Peters, *et al*., 2001, p. xiii. The first offensive action was taken during Operation Deliberate Force, conducted in Bosnia between August 29 and September 14, 1995.
[231] Security Council Res. 1160.

or restore peace and stability in the region."[232] But in the following weeks, it became clear that Russia and/or China, two of the five veto-wielding permanent members of the Security Council, would have vetoed any resolution authorizing use of force in Yugoslavia.[233] Thus, NATO determined to act without Security Council authorization, and unless there was some other authority conferring on NATO the right to use force, it constituted an unauthorized use of force in violation of both the UN Charter and the North Atlantic Treaty.

Aside from the authority conferred by the Security Council, a state or collection of states is entitled to use force in self-defense. Both the UN Charter and NATO recognize the right of the use of force by a state or collective organization (without prior authorization by the Security Council) acting out of self-defense. Article 51 of the UN Charter states that "nothing in the . . . Charter shall impair the inherent right of individual or collective self-defense if an armed attack occurs against a Member of the United Nations…."[234] Pursuant to Article 5 of the North Atlantic Treaty, NATO members agree to assist one another, including by using armed force, if an armed attack occurs against one member, "in exercise of the right of individual or collective self-defense."[235] These provisions do not offer a legal basis for the NATO invasion, however, because Yugoslavia had not attacked any other states – it was a conflict within its own borders. Without an armed attack, no right of self-defense existed as defined by the UN Charter to justify the unauthorized use of force.

Some observers have raised the possibility that Yugoslavia's behavior, even though it had not attacked any other state, would have justified the use of what is referred to as 'anticipatory self-defense.' Whether anticipatory self-defense is permitted under the UN Charter and what conditions would need to be satisfied for an action to qualify as anticipatory self-defense continue to be the subjects of considerable debate. In any event, neither the United States nor NATO relied on anticipatory self-defense as a basis for their actions.[236]

One argument put forth by the United States to support its assertion that the campaign was legal was that the Security Council had implicitly authorized the campaign in the resolutions described above.[237] But that argument is inconsistent with the acknowledgement by the United States and NATO that either Russia, China or both would have vetoed such an intervention.

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[232] Security Council Res. 1199. There was also a third Security Council Resolution that supported agreements reached between Yugoslavia and the Organization for Security and Cooperation in Europe and between Yugoslavia and NATO which called for verification missions and affirmed that the crisis continued to be a threat to peace. Security Council Res. 1203. Again, no use of force was authorized.
[233] Crossette, 1999. Miller, 1999.
[234] UN Charter, 1945, Article 51
[235] NATO, 1949, Article 5.
[236] Schwabach, 2000a, p. 8. For a discussion of anticipatory self-defense as a justification for the NATO campaign in Yugoslavia, see Schwabach 1999, p. 408-412.
[237] Diamond, 1999.

NATO argued that authority for the campaign derived from the fact that intervention was necessary in order to maintain stability in the Balkans and to prevent a humanitarian disaster, particularly in light of the fact that the Security Council was unable to act.[238] Essentially, the argument in support of the mission was that if intervention was not sanctioned by treaty law (the UN Charter) it was sanctioned under international customary law, which permitted interventions to address humanitarian crises.[239] Customary law is "the practice of states which has become accepted as legally binding upon states in their international relations."[240] Scholars have largely rejected this argument because there is little support that such a customary law – a generally accepted and practiced rule – existed prior to the NATO intervention.[241]

The dilemma of whether such a right should exist was described by UN Secretary General Kofi Annan as follows: "On the one hand, is it legitimate for a regional organisation to use force without a UN mandate? On the other, is it permissible to let gross and systematic violations of human rights, with grave humanitarian consequences, continue unchecked?"[242] Even though it is generally believed that a customary law did not exist to authorize the NATO invasion, it is possible that such a norm is now emerging. As one legal scholar noted, "This particular instance of breach of international law may gradually lead to the crystallization of a general rule of international law authorizing armed countermeasures for the exclusive purpose of putting an end to large-scale atrocities amounting to crimes against humanity and constituting a threat to the peace."[243] If such a legal standard were to emerge, it would certainly require a very limited use of force narrowly tailored to the specific needs of ending the humanitarian crisis, and should only occur in an instance where the Security Council had failed to act.

Following the war, the UN's International Criminal Tribunal for the Former Yugoslavia (ICTY) formed a committee to review NATO's actions against Yugoslavia. It was the opinion of the committee that there was no need for an investigation into the environmental damage caused by NATO's bombing campaign.[244] According to the report, "either the law is not sufficiently clear or investigations are unlikely to result in the acquisition of sufficient evidence to substantiate charges against high level accused or against lower accused for particularly heinous offences."[245] However, the committee did admit that environmental information may have been lacking and that NATO's scope of legitimate military targets was unclear.[246] As far as the legality of the bombing campaign as a whole, the ICTY determined that to be outside of its jurisdiction because it is charged with determining how force is used, not when it is used.[247]

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[238] NATO, 2000, p. 24.
[239] For a summary of NATO's position, see the statement of NATO Secretary-General Solana of October 9, 1998, as contained in Simma, 1999.
[240] USEUCOM, 2002, paragraph 7.
[241] Schwabach, 2000a, pp. 78,79, Cassese, 1999; Simma, 1999.
[242] Annan 1999, p. 49.
[243] Cassese, 1999. See also Schwabach 1999, p. 417; Schwabach 2000a, p. 82.
[244] UN, 2000, paragraph 25.
[245] UN, 2000, paragraph 90.
[246] UN, 2000, paragraphs 17 and 47.
[247] UN, 2000, paragraphs 30 to 34.

The Laws of War

Beyond the threshold question of the legality of the use of force in Yugoslavia is the issue specific to the analysis in this report: whether the methods of force used in Pancevo and Kragujevac were consistent with international law. The major relevant tenets of international humanitarian law as applied to armed conflicts are the four Geneva Conventions and their two Additional Protocols. The Geneva Conventions were adopted on August 12, 1949 and entered into force on October 21, 1950. The two Additional Protocols were adopted on June 8, 1977 and entered into force on December 7, 1978. The specific documents that pertain to this report are Geneva Convention IV as it speaks to the protection of civilian persons in time of war and the Additional Protocol I as it relates to the protection of victims of international armed conflicts and the environment.

All of NATO's member states have signed and ratified the 1949 Geneva Conventions and are bound by their terms.[248] The first question in assessing the legality of NATO's actions is whether the Geneva Conventions apply to this particular conflict, even though war was never officially declared in Yugoslavia. According to Article 2 common to the Geneva Conventions, a declaration of war is not required:

> In addition to the provisions which shall be implemented in peace-time, the present Convention shall apply to all cases of declared war or of any other armed conflict which may arise between two or more of the High Contracting Parties, even if the state of war is not recognized by one of them.[249]

Additional Protocol I would also be applicable because it "appl[ies] in the situations referred to in Article 2 common to those Conventions." However, only 17 of the 19 NATO members have ratified Additional Protocol I. The United States is a signatory but did not ratify the treaty, France acceded to the treaty in November 2001 (after the Kosovo campaign), and Turkey has not signed it.[250]

Despite their not having ratified the Additional Protocols to the Geneva Conventions, states are still bound by them to the extent that they reflect applicable customary law. States are bound by customary laws (that they have accepted as such) just as they are bound by treaty laws. For example, the United States Law of War Program defines the law of war as the following:

> The law of war encompasses all international law concerning the conduct of armed conflict, binding on the United States or its individual citizens

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[248] For the United States, treaties are the supreme law of the land along with the Constitution and federal laws. Constitution, 1787, Article VI.
[249] Geneva, 1949.
[250] The ratification status of the treaties described in this report can be found at http://www.icrc.org/ihl.

> contained in either international treaties and agreements to which the United States is a party or applicable customary international law.[251]

There is a great deal of controversy as to which provisions of Additional Protocol I have developed into binding customary law, and thus bind all members of NATO. The United States regards some portions of Protocol I as customary law, and objects to the application of others. But before analyzing whether all provisions of Protocol I will apply to all of NATO's members, we will review whether the actions in Pancevo and Kragujevac violated the relevant treaty terms of Geneva Convention IV and Additional Protocol I.

Analysis of Treaty Terms

The Geneva Convention IV provides general protections against damage to property, including Article 53, which states that "any destruction by the Occupying Power of real or personal property...is prohibited," except where such destruction is rendered "absolutely necessary by military operations."[252] Also, Article 147 includes as a grave breach of the treaty "extensive destruction... of property, not justified by military necessity and carried out unlawfully and wantonly."[253] The protections offered by Geneva Convention IV are thus broad and governed foremost by the concept of military necessity.

Additional Protocol I more specifically addresses the protection of the environment during armed conflict. Article 35 establishes the basic restriction on the methods and means of warfare in terms of protecting civilians and the environment:

1. In any armed conflict, the right of the Parties to the conflict to choose methods or means of warfare is not unlimited.
2. It is prohibited to employ weapons, projectiles and material and methods of warfare of a nature to cause superfluous injury or unnecessary suffering.
3. It is prohibited to employ methods or means of warfare which are intended, or may be expected, to cause widespread, long-term and severe damage to the natural environment.[254]

Unfortunately, Article 35 does not define what constitutes "widespread, long-term, and severe damage to the natural environment." However, the argument can be made that the chemicals released during these bombings do represent such a threat because it has been established that at least some of them have traveled long distances and any illnesses that may be caused by them will likely not be seen for some time to come.

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[251] USEUCOM, 2002, para 7.
[252] Geneva, 1949, Article 53.
[253] Geneva, 1949, Article 147.
[254] Geneva, 1977 Article 35.

One source of guidance to determine the meaning of the terms "widespread, long-term, and severe" is the 1977 Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD). ENMOD, which was written after the Vietnam War and prohibits the use of the environment and environmental modification as a means of warfare, entered into force in 1978 and was ratified by the United States in 1980. The parties to this agreement pledge "not to engage in military or any other hostile use of environmental modification techniques having *widespread, long lasting or severe* effects as the means of destruction, damage or injury to any other State Party" (emphasis added).[255] The Conference of the Committee on Disarmament defined these terms for the purpose of the ENMOD treaty in an Understanding Regarding the Convention:

a) 'widespread': encompassing an area on the scale of several hundred square kilometers;
b) 'long-lasting': lasting for a period of months, or approximately a season;
c) 'severe': involving serious or significant disruption or harm to human life, natural and economic resources or other assets.[256]

The Committee on Disarmament definition was not intended to apply to Additional Protocol I, and it is not itself incorporated into the terms of ENMOD.[257] However, if these criteria were applied to the targeting selection process, the attack of industrial facilities such as those described in this report appears to be prohibited, especially the attacks on Pancevo. As Aaron Schwabach, a legal scholar who has written extensively on the NATO campaign observed, "It seems more likely that the damage at Pancevo can meet at least one of these requirements."[258] For example, it has been established that the air pollution that resulted from the bombings in Pancevo traveled up to hundreds of kilometers to Xanthi, Greece and therefore qualifies as being widespread. The effects are long-lasting because the half-lives of some of the chemicals in question are on the order of decades and certainly fall within the scope of definition presented in the ENMOD Convention. Finally, the effects of the attacks could be considered severe because of the economic disruption that resulted from the bombings and the potential damage of waterways around and adjacent to the facilities.

Part IV of Additional Protocol I requires parties to discriminate between civilian population and its related institutions and legitimate military targets. The basic rule is established in Part IV, Section I, Chapter I, Article 48:

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[255] ENMOD, 1977, Article I.
[256] These Understandings are not incorporated into the Convention but are part of the negotiating record and were included in the report transmitted by the Conference of the Committee on Disarmament to the United Nations General Assembly in September 1976. http://www.icrc.org/ihl.nsf/WebFULL?OpenView&Start=59.
[257] Richards and Schmitt, 1999, pp. 1064, 1065. See also Schwabach, 2000b, p. 129, noting that the definition has not been agreed to by many of the ENMOD signatories.
[258] Schwabach, 2000b, p. 129.

> In order to ensure respect for and protection of the civilian population and civilian objects, the Parties to the conflict shall at all times distinguish between the civilian population and combatants and between civilian objects and military objectives and accordingly shall direct their operations only against military objectives.[259]

As with Article 53 of Geneva Convention IV, whether the bombings in Pancevo and Kragujevac comply with this term hinges on the determination of the military objective. What military objective existed in the case of these bombings? One could certainly argue that the oil refinery was providing fuel for military operations, but is this also true of a car factory, petrochemical plant, and fertilizer plant? In interviews, officials in Kragujevac and Pancevo indicated that their plants did not have any direct strategic military value.[260] Attempts to assess the NATO strategy are impeded, however, because they have not been disclosed to the public (see Section B). We do not believe there is any purpose in keeping that rationale secret after the conclusion of the war, the coming to power of a democratically-elected government in Yugoslavia, and the on-going trial of former President Milosevic in the Hague. If there was some strategic value in attacking these facilities, there remains no reason that this information should remain classified.

In the absence of specific military value of these installations, the bombings would also conflict with the Protocol's protections of civilian populations. Article 51, paragraph 4 states:

> Indiscriminate attacks are prohibited. Indiscriminate attacks are:
> (a) those which are not directed at a specific military objective;
> (b) those which employ a method or means of combat which cannot be directed at a specific military objective; or
> (c) those which employ a method or means of combat the effects of which cannot be limited as required by this Protocol;
> and consequently, in each such case, are of a nature to strike military objectives and civilians or civilian objects without distinction.[261]

Paragraph 5 of Article 51 provides a definition for an "indiscriminate attack" by stating:

> Among others, the following types of attacks are to be considered as indiscriminate:
> (a) an attack by bombardment by any methods or means which treats as a single military objective a number of clearly separated and distinct military objectives located in a city, town, village or other area containing a similar concentration of civilians or civilian objects; and
> (b) an attack which may be expected to cause incidental loss of civilian life, injury to civilians, damage to civilian objects, or a combination

[259] Geneva, 1977.
[260] Nedeljkovic, 2001; Kandic, 2001.
[261] Geneva, 1977.

> thereof, which would be excessive in relation to the concrete and direct military advantage anticipated.[262]

Therefore, under Article 51(b), even in the instance where a military objective exists, a violation occurs when the injury to civilians or damage to civilian objects is excessive.

Additional Protocol I also outlines objectives for the general protection of civilian objects, in addition to the protection of civilians themselves. Chapter III, Article 52, paragraph 2 further underscores the importance of establishing that the destruction of a given target has an actual military value.

> Attacks shall be limited strictly to military objectives. In so far as objects are concerned, military objectives are limited to those objects which by their nature, location, purpose, or use make an effective contribution to military action and whose total or partial destruction, capture or neutralization, in the circumstances ruling at the time, offers a definite military advantage.[263]

Additional Protocol I also takes the natural environment into account by specifically outlining steps that should be taken during a time of war that would allow for its protection. Article 55, paragraph 1 states:

> Care shall be taken in warfare to protect the natural environment against widespread, long-term and severe damage. This protection includes a prohibition of the use of methods or means of warfare which are intended or may be expected to cause such damage to the natural environment and thereby to prejudice the health or survival of the population.[264]

As with paragraph 35(3), the widespread contamination and illnesses caused by the bombing of chemical facilities, which should have been expected, lead us to conclude that this provision was violated.

Article 56 paragraph 1 states:

> Works or installations containing dangerous forces, namely dams, dykes and nuclear electrical generating stations, shall not be made the object of attack, even where these objects are military objectives, if such attack may cause the release of dangerous forces and consequent severe losses among the civilian population. Other military objectives located at or in the vicinity of these works or installations shall not be made the object of attack if such attack may cause the release of dangerous forces from the

[262] Geneva, 1977.
[263] Geneva, 1977.
[264] Geneva, 1977.

works or installations and consequent severe losses among the civilian population.[265]

Chemical plants are not listed among the protected works or installations, and so from the plain reading of the provision, the bombings would not violate its terms. However, the principle underlying this provision is to protect installations containing dangerous forces, and a strong argument can be made that the chemical plants pose a danger similar to the named facilities.[266] As the principles underlying Article 56 were arguably violated, that helps to assess compliance with other provisions of the treaty, including Articles 48 and 55.

The persistence and health risks from chemicals are, in some cases, comparable to radionuclides. For example, estimates of PCB half-lives vary from months to many years in soil, depending upon the chlorination level of the monomers and the make-up of the environment in which they are deposited (organic content, biotic content, etc.).[267] Half-lives of dioxins in soil can be as long as 12 years while the half life of 1,2-dichloroethane can be as long as 30 years.[268] Some radionuclides, such as strontium-90 and cesium-137, have half-lives of 29 and 30 years respectively. In addition, certain chemical compounds described in this report are carcinogenic, as are radionuclides.

Because the effects and risks of some chemical pollutants are comparable to some radionuclides, we may conclude that the installations should be treated in the same manner as nuclear facilities. Although this treatment might not currently be consistent with state practice, it should be adopted.[269] One international law professor notes, "[Article 56] should also apply to such installations as the petrochemical plant in Pancevo, the destruction of which caused severe atmospheric pollution of the town and its surrounding area by chemical substances, some of which can result in cancerous diseases and genetic mutations."[270]

Another way in which the Pancevo bombing may be viewed as violating Article 56 is that it posed some risk to a nuclear power plant located in a non-combatant country, Bulgaria. Six nuclear power reactors are located in Bulgaria at the Kozloduy station which is downriver from Yugoslavia along the Danube. The potential exists for operational problems if contaminants in the Danube interfere with the condenser cooling systems of the power plant. Four of the reactors are of an older design (VVER 440-230) which is especially vulnerable to accidents. The U.S. National Academy of Sciences noted in a 1995 report that the VVER 440-230 reactors "…do not have containments, a major difference in safety from international standards. The early models (VVER 440-230)

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[265] Geneva, 1977.
[266] There is no official language to define the term "dangerous forces" within the Geneva Conventions or their additional protocols. They only specify "installations containing dangerous forces" as dykes, dams, and nuclear facilities.
[267] ATSDR, 2000, p. 507.
[268] ATSDR, 2001, p. 169.
[269] See Schwabach, 2000b, p. 128.
[270] Egorov, 2000.

were not designed to withstand major earthquakes or the level of cooling water losses which Western reactors are designed to survive, have less redundancy in their safety systems, lack emergency operating procedures and training simulators to assist operation in responding to upset conditions, and otherwise fall far short of internationally accepted safety standards, such as those of the IAEA. As a result, some of the VVER 440-230s have been shut down (in Russia and Armenia and also in eastern Germany)."[271]

The risk of disruption of nuclear power plant operation and the elevated potential for an accident as a result of spilling oil into the Danube was known at the time. IEER raised the issue in a press release on May 11, 1999, while the bombing was going on.[272]

Finally, Article 57, paragraph 2 outlines the precautions that should be taken in order to prevent civilian casualties or the destruction of civilian object:

> (i) do everything feasible to verify that the objectives to be attacked are neither civilians nor civilian objects and are not subject to special protection but are military objectives …
> (ii) take all feasible precautions in the choice of means and methods of attack with a view to avoiding, and in any event to minimizing, incidental loss of civilian life, injury to civilians and damage to civilian objects.
> (iii) refrain from deciding to launch any attack which may be expected to cause incidental loss of civilian life, injury to civilians, damage to civilian objects, or a combination thereof, which would be excessive in relation to the concrete and direct military advantage anticipated.[273]

"Feasible" has been interpreted as "[t]o take the necessary identification measures in good time in order to spare the population as far as possible."[274] Whether these criteria were fulfilled is a factual inquiry that has not been satisfied.

The continued secrecy regarding the "direct military advantage anticipated" in the bombing of Pancevo must end in order to arrive at a judgment as to whether the necessary steps were taken. This continued secrecy is not justified, especially since the war is over, the government in question has been removed from office in an election, and the president of the country at the time, Slobodan Milosevic, is facing prosecution for war crimes.

In sum, whether violations existed depends largely on the facts around the targeting strategy and the military objectives behind those targets. As Aaron Schwabach explains:

> If. . . the [Pancevo] complex was in fact a dual-use facility, the principles of military necessity, proportionality and humanity become relevant. The destruction of the complex has caused measurable, long-term harm to the

[271] SDA, July 1999, pp. 13, 14.
[272] IEER, May 1999.
[273] Geneva, 1977.
[274] HRW, 2000, citing the International Red Cross Commentary on the Additional Protocols.

> local environment, and may have adverse consequences for the lower riparians of the Danube as well as for the already-threatened Black Sea. These costs must be balanced against the military advantage gained.[275]

One provision that does not factor in military considerations is the protection against targeting installations containing dangerous forces. Although chemical plants are not listed in that provision, the targeting of a chemical plant that poses the same risk as other specified installations (including nuclear plants) certainly violates the spirit of that provision. This is particularly true given that the chemical releases from the chemical plant as a result of the bombings may have increased the risk of an accident at a downstream nuclear plant.

The Application of Protocol I to the United States

Because the bombings in Yugoslavia were principally carried out by the United States, any assessment of liability requires an analysis of which of Protocol I's provisions apply to the United States through customary law.[276] Essentially, Additional Protocol I incorporates some concepts that were considered to be protections already guaranteed by customary law, and the United States acknowledges those terms to be binding on its actions. The United States does not accept other provisions, including those addressing the environment, as customary law. Of all of the terms described above, the United States acknowledges that the general protections of civilians are customary law or acceptable practice,[277] but specifically objects to the treatment of Articles 35(3), 55, and 56, those that specify the protection of the environment, as customary law.[278]

As the United States accepts the principles relating to discrimination, necessity and protection of civilians, it can be held accountable under those terms. As for the environmental provisions, even though the United States had objected to their inclusion as customary international law, that is not necessarily the end of the inquiry into U.S. liability. Despite U.S. objections, it is widely believed that a customary law does exist with respect to the protection of the environment during armed conflict. Additional Protocol I has been ratified by over 150 countries, and its prohibition of warfare that would "cause widespread, long-term and severe damage to the natural environment" was included in the preamble of another treaty in 1980.[279] Protection of the environment in

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[275] Schwabach 2000b, pp. 137, 138.

[276] The United States committed over 700 of the 1055 aircraft used in Operation Allied Force and U.S. aircraft flew more than 29,000 of the 38,000 sorties flown during the campaign. However, it is impossible to say whether it was U.S. aircraft that bombed the facilities in Pancevo and Kragujevac because this information is classified. See Peters, *et al,* 2000, pp. 23 to 36.

[277] Including Articles 35, paragraphs 1 and 2 but not 3, Article 48, Article 51, except paragraph 6, and Article 52.

[278] McDonnell, 2002, n. 315 citing U.S. Army, *Operational Law Handbook* (Capt. Jeanne M. Meyer & CDR, Brain J. Bill eds., 2002) and Department of Defense, *Conduct of the Persian Gulf Conflict, An Interim Report to Congress* 12-3 (July 1991).

[279] The Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May be Deemed to be Excessively Injurious or to Have Indiscriminate Effects, CCW, 1981. Although the United States. ratified this treaty, it qualified its acceptance with the understanding that the provision in

wartime is an increasing global concern. For example, when Iraq set Kuwaiti oil wells on fire, the willful environmental damage received universal condemnation.[280] Similar prohibitions appear in the Statute of the International Criminal Court.[281] Furthermore, the International Court of Justice, in its advisory opinion on the legality of the threat or use of nuclear weapons, stated that "[s]tates must take environmental considerations into account when assessing what is necessary and proportionate in the pursuit of legitimate military objectives. Respect for the environment is one of the elements that go to assessing whether an action is in conformity with the principles of necessity and proportionality."[282]

For the United States to remain unbound by a customary law, it must have consistently objected to the existence of the rule, which the U.S. might argue that it has done. However, in some instances, customary laws become sufficiently universal that they develop into a type of peremptory norm (known in international law as *jus cogens*) to which a state cannot object.[283] Many legal scholars viewing the progress of laws on environmental protection in wartime have argued that "[w]illful serious damages to the environment in armed conflict" is developing into a type of preemptory norm. As the concept develops, regardless of U.S. acceptance of the customary law, it may be required to adhere to these norms.[284]

Regardless of whether the United States accepts environmental protections as customary law, or whether these provisions will eventually be viewed as peremptory norms, it is clear that a shift of understanding has occurred in recent years that consideration must be given to protection of the environment during warfare. We believe that the United States, as the leading economic and military power, should hold itself to these standards, and should adhere to the prohibition of weapons and means of warfare expected to cause severe damage to the environment.

Another consideration in holding NATO countries accountable for damage caused in the bombings in Pancevo and Kragujevac is that, at the time, 16 of the 19 NATO members were parties to Additional Protocol I. Assuming that the United States was the principal

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question "which refers to the substance of provisions of article 35 (3) and article 55 (1) of additional Protocol I to the Geneva Conventions for the Protection of War Victims of August 12, 1949, applies only to States which have accepted those provisions." www.icrc.org/ihl.

[280] Uhlmann, 1998, p. 120.

[281] The Rome Statute of the International Criminal Court includes in the definition of war crimes (one of the crimes over which the court has jurisdiction) "Intentionally launching an attack in the knowledge that such attack will cause incidental loss of life or injury to civilians or damage to civilian objects or widespread, long-term and severe damage to the natural environment which would be clearly excessive in relation to the concrete and direct overall military advantage anticipated." Rome Statute, 1998, Article 8, para. 2(b)(iv).

[282] ICJ, 1996, paragraph 30.

[283] Under international law, a *jus cogens* norm needs to be "accepted and recognized by the international community of states as a whole." Vienna Convention, 1969, Article 53. However, it is not required that *each* state has accepted the norm, and objectors are still bound by its requirements. A clear example of a recognized *jus cogens* norm is the prohibition of genocide. Uhlmann, 1998, p. 112.

[284] Uhlmann, 1998, p. 122-124.

perpetrator of the bombings in Pancevo and Kragujevac, those NATO members that directly or indirectly assisted in these bombings may be liable under the theory of aiding and abetting to the extent that they were aware of the U.S. actions.[285]

Finally, even if the environmental provisions are not binding on the United States as customary laws, the United States is a signatory to the Additional Protocol I. As such, pursuant to the laws of treaty making, the United States is obligated not to undertake acts that would violate the object and purpose of the treaty.[286] Attacks that are widely indiscriminate, if that could be established, could be viewed as going against the object and purpose of Additional Protocol I.

B. Targeting Criteria

The specific criteria by which targets in Yugoslavia were selected have not been released to the public. In order to obtain an official rationale for the bombings of the facilities presented in this report, a request was made by IEER in January 2001 under the Freedom of Information Act to the United States Department of Defense for documents outlining the strategic value of these plants. The request was denied in a rather odd way. A document was sent to IEER that contained nothing but blank pages showing classification marks that had been cancelled.[287] A subsequent appeal was also denied.[288] Other non-governmental organizations such as Amnesty International and Human Rights Watch have also called into question the legality of certain aspects of the NATO air campaign including target selection.[289] Now that we are three years post-Operation Allied Force, the military should be willing to declassify documents, without which the issue cannot be put to rest in a definitive manner. At the very least, the analysis in this report has provided additional and sufficient evidence to raise serious questions about the legality of these bombings,

In its final Kosovo After-Action Report to Congress, the U.S. Department of Defense stated:

> Legal reviews of selected targets were conducted at successive echelons of the chain of command. Targets nominated for approval by SACEUR [Supreme Allied Commander, Europe] received legal reviews in the field. Targets nominated that met the criteria requiring NCA [U.S. National Command Authorities] approval received detailed legal scrutiny by the Legal Counsel to the Chairman of the Joint Chiefs of Staff and by the DOD General Counsel. Legal reviews involved evaluation of certain

[285] McDonnell, 2002, pp. 103, 104
[286] Vienna Convention, 1969, Article 18.
[287] Ellis, 2001.
[288] Cooke, 2002
[289] Amnesty, 2000; HRW, 2001, Chapters 16 and 19.

> targets as valid military targets as governed by applicable principles of the laws and customs of armed conflict.[290]

The U.S. Air Force targeting guide states:

> A target must qualify as a military objective before it can become a legitimate object of military attack. In this context, military objectives include those objects that by their nature, location, purpose, or use make an effective contribution to military action, or whose total or partial destruction, capture, or neutralization offers a definite military advantage. The key factor is whether the object contributes to the enemy's war fighting or war sustaining capability. Consequently, an identifiable military benefit or advantage should derive from the degradation, neutralization, destruction, capture, or disruption of the object.[291]

The U.S. Air Force generally recognizes the civilian population as being "immune" from attack unless they become active participants in the hostilities. While it is illegal for civilians to be used as human shields, the U.S. policy on targets shielded by civilians is not clearly defined. Presumably it would be considered on a case-by-case basis in which the military objective would be weighed against any potential loss of life. That is, the possibility of civilian deaths does not immediately make an attack illegal, because the proportional value of the target must be taken into account. If the value of the target does not warrant the loss of civilians, the target should not be attacked. However, the Air Force does state that in these cases the protection of civilians is "compromised."[292]

The Air Force also admits that "controversy exists over whether, and under what circumstances, other [civilian] objects…can properly be classified as military objectives."[293] The main factor in determining an object's status is whether "the object makes an effective contribution to the adversary's military action."[294]

Using these criteria, the U.S. Air Force determines objects such as oil depots to be legitimate military targets.[295] However, it also states that "[f]actories, workshops, and plants that *directly* support the needs of the enemy's armed forces are also generally conceded to be legitimate military objectives."[296] Given the importance of this determination, the targeting rationale needs to be made public in order to ensure that civilian monitoring of military activities can take place.

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[290] DOD, 2000, p. 24.
[291] USAF, 1998, p. 12.
[292] USAF, 1998, p. 149.
[293] USAF, 1998, p. 147.
[294] USAF, 1998, pp. 147 to 148.
[295] For example, a theater objective in Iraq during the 1991 Gulf War was to sever Iraqi supply lines by destroying key electrical grids and oil storage. USAF, 1998, p. 33.
[296] USAF, 1998, p. 147.

Chapter 6: Main Findings and Recommendations

Main Findings

1. ***To date, there is insufficient data to accurately quantify the effect that the bombings have had or will have on the environment and on public health, or both.***

Given the lack of pre-conflict pollution data, no baseline levels could be established. Therefore, it is impossible to determine exactly how much pollution was caused by the NATO bombings and what adverse public health effects can be expected. In order to do this assessment, environmental and public health monitoring data must be made available to the public so that comparisons can be made between pre-war and post-war conditions.

2. ***The NATO bombings did result in the release of significant amounts of toxic substances and exacerbate existing conditions that were not ideal by all accounts.***

The bombings in Pancevo resulted in a 1,2-dichloroethane release and mercury release, both of which pose potentially long-term threats to the local population and local environment. These examples clearly illustrate the unintended effects that can result from the bombing of a chemical facility even when precision weapons are used and perform according to specifications.

3. ***The cleanup process has been made more costly and possibly more risky to the public because of the long delay in starting the clean-up process.***

As time passed and aggressive cleanup was delayed, the problems of environmental remediation became increasingly complex due to the spread of the contaminants. UNEP admits that cleanup needed to happen sooner rather than later: "[t]he costs associated with environmental clean-up and remediation increase overtime [sic] due to increased infiltration or spread of chemical contaminants."[297]

4. ***The health risks to civilians may be increased as a result of the NATO bombings.***

Civilians can be exposed to these pollutants via several pathways that include inhalation, the use of contaminated groundwater, and the consumption of contaminated fish. While in some cases the exposure is not immediate, there is a definite public health risk over time.

5. ***The data necessary to characterize the present situation in Pancevo and Kragujevac are lacking***.

[297] UNEP, October 2001, p. 5.

Monitoring data was either not made available or does not exist. It is impossible to conclude definitively what are the major risks and how many of these risks exist today due to the bombings. As of this writing, the most recent data that could obtained for this report is almost two years old. As a result, the current risks to public health and the environment can only be estimated.

6. ***Monitoring and cleanup programs are urgently needed in Pancevo and Kragujevac***.

Monitoring programs will certainly help fill many of the gaps described in this report. However, monitoring does not equal remediation. Urgent steps need to be taken in order to ensure that the problems do not worsen.

7. ***Persuasive evidence indicates that humanitarian law may have been violated in the NATO bombing campaign, notably with respect to the bombing of Pancevo.***

A number of aspects of international humanitarian law, particularly the 1977 Additional Protocol I to the Geneva Convention, restrict the bombing of civilian facilities. However, because the U.S. government has refused to release its targeting criteria or the military objectives that were accomplished by the bombing of these facilities a definitive conclusion is difficult to reach as to the legality of the targeting of some facilities at Pancevo and Kragujevac.

Recommendations

1. ***The entire issue of bombing civilian facilities to accomplish military objectives needs to become the subject of a rigorous public inquiry. Such an inquiry should include consideration of immediate and/or environmental and health damage that could be inflicted on the country or in neighboring countries sharing ecosystems with the countries at war.***

Such an inquiry is urgently needed because it relates to the specific bombings that are covered in this report and because precision bombing is evolving into a principal component of military strategy adopted by NATO members. Other countries may also adopt precision bombing in the future.

2. ***Environmental cleanup needs to be expedited so as to close the time gap between the conflict and remediation.***

At the time of this writing, over three years have elapsed since the bombings ended in 1999. Only in recent months have sincere, large-scale remediation efforts begun. The main reason given is a lack of funds to specifically cover for cleanup costs. UNEP, or some other international body, should develop a system whereby funds can be allocated immediately in the case of a severe environmental problem. Even if a country's regime is not politically desirable, its people should not have to suffer long-term consequences to their environment.

3. Information regarding past bombings of civilian industrial facilities should be available to the public for legal review.

A thorough legal review under international humanitarian law of bombings such as those in Pancevo and Kragujevac cannot take place without the full disclosure of information, including information on the rationale for choosing these targets, by the militaries that carried out those attacks. Such disclosure would foster trust between the public and military by allowing the military to prove that these attacks were necessary to achieve concrete military objectives.

4. Until such time as the United States recognizes the legal prohibitions on environmental damage during wartime, the United States should conduct no bombings of civilian industrial facilities containing any dangerous substances likely to be released into the environment.

The United States should ratify Additional Protocol I to the Geneva Conventions relating to the protection of victims of international armed conflicts and join the International Criminal Court which has jurisdiction to prosecute violations of these protections. At minimum, the United States should acknowledge that the prohibitions of methods of warfare intended or likely to cause severe environmental damage have developed into binding customary law. Future bombing of civilian industrial facilities that could release dangerous substances into the environment or cause long-term damage to health and the environment would raise the same questions of legality as those in Pancevo and Kragujevac. Until such time as the United States has adopted the international legal framework on the protection of victims of international armed conflicts as binding upon itself, it should not bomb or consider bombing these types of facilities. This recommendation applies to any similarly situated country outside of the existing legal framework.

5. Extensive and on-going monitoring programs should be established to ensure that the cleanup in Yugoslavia is effective and that unknown sources of pollution do not remain in the environment.

Presently, large uncertainties remain about the extent of the pollution (e.g. contamination of the waterways around Kragujevac by PCBs). Monitoring programs should be established immediately to prevent the public's exposure to unforeseen dangers. Furthermore, these monitoring programs would measure the effectiveness of the cleanup and ensure its thoroughness.

6. The cleanup process should be more transparent.

The public, whether it be the people living in Yugoslavia or other interested parties, should have greater access to information on the status of cleanup activities and the health of the local environment. Such openness would foster trust between the institutions carrying out the cleanup and those whom they are trying to protect. UNEP stresses the importance of openness as one of the lessons learned from its first year of

operations in Yugoslavia. It states that "ownership, availability, and distribution of data during clean-up activities should be clearly defined between all relevant stakeholders including industrial partners, workers, municipalities, environmental authorities, etc. This will ensure the efficient implementation of cleanup activities with decisions on remediation activities taken with all possible data available."[298]

[298] UNEP, October 2001, p. 5.

Appendix

This is a summary table of some of the chemicals that have been discussed in this report.

Chemical Molecular Formula CAS No.[1]	Sources/ Uses	Human Health Effects	Environmental Fate	Standards and Regulations[2]
Ammonia (NH_3) 7664-41-7	- Naturally occurring compound - Produced and used in a variety of industrial situations	- Causes eye, skin, and respiratory problems. - Chronic exposure can lead to liver disorders.	- In the atmosphere it generally returns through rainfall - In oxygen rich environments it binds tightly to organic matter in soil and water.	- Occupational exposure limit (based on 8 hr. work day) is 50 ppm (or 35 mg/m^3) [OSHA][3]
Nitrogen Dioxide (NO_2) 10102-44-0	- Naturally occurring - Used industrially as an oxidizing agent - Product of fuel combustion	- Chronic exposure to high levels can cause pulmonary problems.	- Plays a role in ground level ozone (smog) formation and - Expected to decompose to nitric acid in moist soil and water and volatilize from dry soil	- Ambient air quality standard is 0.053 ppm (or 100 $\mu g/m^3$) [EPA] - Occupational Limit of 5 ppm (9 mg/m^3) [OSHA]
Sulfur Dioxide (SO_2) 7446-09-5	- Naturally occurring - Used in preservatives - Used as an oxidizing agent - Used as a disinfectant	- Found to be carcinogenic in animal studies. - Irritant to skin, eyes, and respiratory tract	- Removal from atmosphere through wet and dry deposition - Can play a role in acid rain - Behavior in soil is dependant upon pH and organic content	- Occupational limit of 5 ppm (13 mg/m^3) [OSHA]
Vinyl Chloride (C_2H_3Cl) 75-01-4	- Monomer of polyvinyl chloride (PVC) - Used in various organic synthesis reactions	- Confirmed human carcinogen - Chronic exposure can damage liver and central nervous system	- Expected to be mobile in soil. - Estimated atmospheric half life of 55 hours - Volatilizes from water but fate is dependant on salt content.	- 2 µg/L safe drinking water limit [EPA] - Occupational limit of 1 ppm over an 8 hour period. [OSHA]
1,2-dichloroethane ($C_2H_4Cl_2$) 107-06-2	- Used in production of vinyl chloride - Organic Solvent	- Classified as a probable human carcinogen - Acts as a central nervous system depressant	- Evaporates rapidly - Large soil releases will leach into groundwater - Degrades in atmosphere by reaction with hydroxyl radicals	- 5 µg/L safe drinking water limit - Occupational limit of 50 ppm over an 8 hour period.

Chemical Molecular Formula CAS No.	Sources/ Uses	Human Health Effects	Environmental Fate	Standards and Regulations
Sodium Hydroxide (NaOH) 1310-73-2	- Used a variety of industrial and laboratory situations	- Can cause respiratory, eye, and skin irritation. - Acute exposure can cause permanent damage	- Reactive species whose environmental fate is difficult to predict. - Large spill would alter pH and ion content in spill area. - Dissociates completely in water.	- No standards in Clean Water or Clean Air Act although it has been designated a hazardous substance. - Occupational limit of 2 mg/m^3 over an 8 hour period. [OSHA]
Hydrochloric Acid (HCl) 7647-01-0	- Used in a variety of industrial and laboratory situations	- Can cause respiratory, eye, and skin irritation - Acute exposure can cause gastric hemorrhage and circulatory collapse.	- Very reactive species - Large spill would alter pH and ion content in spill area - Dissociates completely in water	- Listed as a hazardous substance under the Clean Water Act and a hazardous air pollutant under the Clean Air Act. - Occupational Limit of 5 ppm. (7 mg/m^3) [OSHA]
Elemental Mercury (Hg) 7439-97-6	- Used in electrolysis - Agent in industrial reactions - Naturally occurring element	- Damages central nervous system - Eye problems and skin disorders from chronic exposure - Can be transformed to methylmercury in the environment which can bioaccumulate.	- Very volatile element on surfaces - Dense element that sinks in water systems - Undergoes biotransformation	- 2 μg/L safe drinking water limit [EPA] - Listed as a hazardous air pollutant under the Clean Air Act - Occupational limit of 0.1 mg/m^3 [OSHA]

Chemical Molecular Formula CAS No.	Sources/ Uses	Human Health Effects	Environmental Fate	Standards and Regulations
Total Petroleum Hydrocarbons A variety of compounds fall under this category.	- TPH is a term used to classify hundreds of compounds that come from crude oil.	- Great variation in toxicity. - Chronic exposure to some compounds can permanently damage the central nervous system.	- Can undergo bulk or separated migration - Some species can be biodegraded - Some species are volatile - Lighter products such as gasoline are more mobile than heavier ones such as fuel oil.	- No standards for total petroleum hydrocarbons as a whole.
Phosgene 75-44-5	- Used in preparation of many organic chemicals - Found in pesticides - Excellent chlorinating agent - Naturally occurring - Regulated under the chemical weapons treaty	- Irritant to eyes, skin, and respiratory tract - Symptoms may not be seen immediately after exposure - Short-term exposure can cause lung edema. Chronic exposure can cause fibrosis of the lungs. - Acute exposures can be fatal.	- Expected to hydrolyze rapidly in soil and water, but this may be delayed in water because of slow dissolution - Phosgene that does not hydrolyze in soil is expected to be very mobile. - Has a long half life in the atmosphere and can be expected to travel long distances	- Listed as a hazardous substance under the Clean Water Act and Clean Air Act. - Occupational exposure limit of 0.1 ppm (0.4 mg/m^3) [OSHA]
Polycyclic Aromatic Hydrocarbons (PAH) Variety of compounds fall under this category	- Formed during incomplete combustion of fuels. - Usually occur as mixtures of several compounds - Industrial uses in dyes, plastics, pesticides, and other items.	- Probable human carcinogens - May cause reproductive disorders	- Can be transported long distances in atmosphere - Bioaccumulates in aquatic and terrestrial organisms - Expected to have low mobility in soil	- Safe drinking water limit of 0.2 μg/L [EPA] - Occupational limit of 0.2 mg/m^3 [OSHA]

Chemical Molecular Formula CAS No.[1]	Sources/ Uses	Human Health Effects	Environmental Fate	Standards and Regulations[2]
Polychlorinated Biphenyls (PCB) 1336-36-3	- Used widely as coolants and lubricants in electrical equipment. - Production in the United States was stopped in 1977.	- Probable human carcinogen - Likely endocrine disrupter	- Subject to long distance atmospheric transport. - Mobility varies with species but generally thought to have low mobility in soil. - In water column PCBs tend to sorb to sediments and suspended solids. - Very stable and persistent compounds - Contaminates fish - Can be passed from mothers to nursing infants.	- Listed as a hazardous air pollutant under the Clean Air Act. - 0.5 μg/L safe drinking water limit [EPA] - Recommended occupational exposure limit of 0.001 mg/m^3 over a 10 hour period [NIOSH][4]

Source: Agency for Toxic Substances and Disease Registry, Hazardous Substance Data Bank web site
[1]Chemical Abstract Service Identification Number
[2] Standards given are federal standards for the United States alone
[3] Occupational Safety and Health Administration
[4] National Institute of Occupational Safety and Health

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