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Careful Chemical Brush Control Cuts Stream Contamination • The Benefits of Burning Early

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COVER: Forest researcher Michael Newton collects a sample of stream water to be analyzed for herbicide concentration. The studies are being made to provide forest managers with a scientific basis for the development of spraying policies which will help hold stream contamination to a minimum. See story on page 10.

"THINGS ARE BAD NOW, but are likely to get much worse unless strenuous efforts at improvement are made."

No doubt, this disturbing observation has application to many of today's problems. When it was expressed recently by the President's Science Advisory Committee, however, the subject at hand was the diminishing quality of our land, our water, and our air.

Can we restore and maintain the quality of our environment? Our complex industrial and technological society is generating ever-increasing volumes of waste. Yet, the environment's capacity to assimilate these wastes is limited. How, then, are we to abate or control pollution?

Who is the "culprit?"

The most obvious answer, of course, is simply to force the discontinuance of those activities that pollute. This drastic approach may merit consideration in some instances. But too often, the disposal of wastes into the environment is considered a problem that can be solved merely by identifying the "culprit" and making him stop. Definitive solutions will be more difficult to come by, for waste production is an integral part of life processes and human endeavor. To put it another way, we all contribute to the pollution problem.

Most of the early attempts to develop pollution abatement and control programs took place at the local level. It eventually became obvious, however, that more than local action was required. State governments entered the field, and more recently, the Federal government has stepped up its partici-

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OSU Research Expands . . .

Pollution Control for a Quality Environment

By **Robert M. Alexander**

pation. Federal action has included: offering subsidies to areas to help develop new, or improve existing control devices; setting minimum standards to apply under Federal jurisdiction if state or local standards which meet these minimums are not developed; encouraging the establishment of planning and control bodies on a regional or "shed" basis, rather than according to political boundaries; and fostering the incorporation of resource quality into total resource management planning.

In Oregon, substantial progress has been made in abating a number of the more obvious sources of pollution. But less apparent forms of pollution—for example, the subtle effects of pesticides in food chains, in combination with increasing population and intensified industrial development, have offset many of the gains.

Reversing the situation

In an effort to reverse this situation, the Oregon Agricultural Experiment Station is expanding its research activities to include the study of environmental quality problems posed by more people, more industry, and new practices and materials which breed more subtle forms of pollution. This issue of *Oregon's Agricultural Progress* is devoted to reports on several of the specific programs now under way.

The Oregon Station's basic research on pollution is aimed at a better understanding of the biological and physical processes which occur in nature, and the effect of various pollutants and contaminants on these processes. Many of these projects are supported by substantial grants from Federal agencies. Major efforts include learning more about how pesticides affect the environment and how the introduction of wastes affects aquatic resources.

Essential information provided

While research dealing with specific pollution control measures has been somewhat limited, work in the basic areas is providing information essential to such measures. A noteworthy case in point is the recent development of water quality standards by the Oregon Sanitary Authority. Knowledge obtained through the Station's extensive work in water pollution biology—such as the effects of low dissolved oxygen levels and toxic materials on aquatic organisms—is vital both in developing and enforcing these standards.

Pollution abatement programs for Oregon waters have concentrated to date on improving the principal rivers, and have sought to abate three chief problems: pathogenic organisms from human wastes, toxic materials from industrial sources including metal processing plants, and heavy loadings of organic wastes high in solids content and requiring oxygen for breakdown. The major sources of these heavy loadings, which deplete dissolved oxygen, cause slime growth, and form bottom sludge deposits, are the pulp and paper industry, the food processing industry, and domestic sewage.

Water problems that soon will require attention include increasing levels of nutrient salts such as nitrogen and phosphorus, synthetic chemicals that break down slowly, radioactive materials, and temperature increases or "thermal pollution."

Air pollution abatement and control programs have centered on the more obvious primary pollutants such as industrial smokes and dusts that contain high levels of contaminant particles or involve foul odors.

Smog potential is high

Secondary air contaminants produced through photochemical reactions in the atmosphere are not yet a problem of consequence in Oregon. However, the potential is high for urbanized areas in the western part of the state. Both the meteorological and topographical features of this area are conducive to various secondary air pollution problems, including photo-

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Field burning is an essential practice in Oregon grass seed production today. But field burning also injects considerable volumes of smoke into the atmosphere, as well as contaminant particles and gaseous pollutants.

The Benefits of Burning Early

Oregon's famed grass seed industry

can benefit from early burning

on at least two top-priority counts

WILLAMETTE VALLEY grass seed growers can boost yields and reduce air pollution by burning their fields early.

That's the finding in the first round of field-burning trials being conducted by OSU agronomist David Chilcote and OSU engineer Richard Boubel.

Field burning is an essential practice in Oregon grass seed production today. Among its many benefits: burning is the only method yet known to control three crippling problems — blind-seed disease, ergot, and grass seed nematode; burning checks fungi, weeds, rodents, and insects; burning effectively and economically cleans up post-harvest straw and stubble.

But field burning also is a source of air pollution. When conditions permit, smoke from the burning fields reduces visibility and may cause serious traffic problems when it blows across highways. In addition, field burning injects contaminant particles and gaseous pollutants into the valley's atmosphere.

Trials launched

In search of a solution, the OSU researchers launched a series of field-burning trials in 1965. Test burning was started in perennial ryegrass plots on August 7 and continued for 10 weeks. Fields were burned at different times of the day and under a wide range of weather conditions. Some plots were left unburned; on others, straw was removed by raking and baling. In addition, half of each test plot was treated with herbicides. In the summer of 1966, the crop was harvested and seed yields were compared.

As shown in Table 1, burned plots outproduced unburned plots straight across the board, while getting rid of post-harvest straw by raking and baling did not appear to improve yields.

Table 1 also shows, however, that plots burned early yielded 53 pounds more seed per acre than plots burned late in the season. And at extreme burn dates, the difference is even more pronounced. Plots burned on August 7 (earliest burn date in the tests) yielded 1,191 pounds of seed per acre. Plots burned on October 21 (latest test-burn date) produced only 847 pounds.

TABLE 1. EARLY BURNING INCREASES SEED YIELDS

Treatment	Seed yield
	Lbs./A.
Burned early (8-7 to 8-13)	924
Burned mid-season (8-21 to 9-17)	900
Burned late (9-23 to 10-21)	871
Not burned	750
Not burned, raked	740

Why did early-burned plots yield best?

Throughout the 10-week burning operation, detailed records were kept of wind conditions and of temperatures and moisture levels in soil, air, and straw. Straw moisture content at burning time proved to be particularly important in subsequent seed yield. As shown in Table 2, substantially higher yields were produced where straw moistures ranged from 5% to 12% at burn time.

TABLE 2. YIELDS ASSOCIATED WITH LOW STRAW MOISTURE

Straw moisture	Seed yield
	Lbs./A.
Very low (5-7%)	1,094
Low (8-12%)	1,113
Medium (13-16%)	886
High (17-24%)	808

Moreover, the surface temperatures were higher and stayed hotter longer in test plots burned under low straw-moisture situations. This, Chilcote believes, helped stimulate higher yields through improved thinning (greater reduction of the "sod-bound" effect), better control of smothering (a condition which inhibits the emergence of vigorous regrowth), and increased fertilizer efficiency.

A potential drawback of these hotter burns is that they are more difficult to control. On the other hand, more help is available early in the burning season if school-age youths are employed. Lack of manpower later in the season, Boubel points out, often leads to undermanned burns or concentrated burning on weekends.

In the Willamette Valley, of course, low straw moistures prevail in midsummer when humidities are still low and before green regrowth has emerged. Here's where cutting down air pollution enters the picture, for midsummer—early in the burning season—also is the best time to burn from the standpoint of air quality.

At the outset, early burns produce less smoke. In the tests, late burns gave off large amounts of dense smoke; early burns produced smaller volumes of less opaque smoke.

The tests showed, in fact, that the total amount of suspended particles emitted during burning is directly related to the length of time from harvest to burn. This means that more contaminant particles will be put into the air

Late-season burns, the tests showed, give off large amounts of dense smoke; burns conducted early produce smaller volumes of less opaque smoke.

by late-season burning than by burning immediately after harvest.

The quantities of residue—including unburned carbon and ash—left on the ground following a test burn also were directly related to the number of days between harvest and burn. With moderate winds, large amounts of these residues are blown into the air and they eventually settle downwind from burned fields. By reducing the volume of air-borne residue, early burning minimizes this pollution problem.

Atmospheric inversion

Air generally becomes cooler with increases in height. Quite often, though, the reverse is true. This is known as atmospheric temperature inversion, and because it prevents lower air from rising, it limits the dispersion or scattering of smoke and other emissions into the atmosphere.

During the field-burning season in the Willamette Valley, two inversion layers may be present at the same time—one at the earth's surface and one several thousand feet above the valley floor. Earlier in the summer, the layer at the surface disappears during warm afternoons. In the fall, however, when the low sun brings less heat, both inversion layers persist both day and night. Thus, burning earlier in the summer means fewer smoke buildups.

Competition for the air-shed also can be important. Slash burning in Oregon forests begins in the fall. If field burning were completed before slash burning got under way, there would be less smoke and fewer particles for the air-shed to handle during fall months.

Higher yields were harvested from test plots that were burned early.

Since 1964, a daily "advisory" has been issued during the burning season to let grass seed growers know in advance the degree of dispersion possible at a given time. These advisories are based on forecasts of the atmospheric conditions that determine the dispersion rate of smoke and other emissions into the atmosphere. Working to make the advisory a more valuable decision-making tool is Robert Black, U. S. Weather Bureau meteorologist stationed at OSU.

How well air pollutants will disperse usually is decided by two conditions: the depth of the air layer through which dispersion is possible and the wind speed within this layer. When combined, these conditions are used to estimate the volume of air available for dispersion and dilution.

The mixing depth — the depth through which turbulent mixing of air and pollutants will take place—usually is confined to the depth in which temperatures of the atmosphere above the earth's surface decrease 5 degrees F. for each 1,000 feet of elevation. Wind and surface heating by the sun increase this depth during the day. In summer, however, the depth is seldom increased beyond the level of the inversion layer found at several thousand feet. But when the lower inversion layer near the surface fails to disappear, the mixing depth is extremely shallow, perhaps only a few hundred feet.

An advisory is calculated by first measuring the vertical temperature profile at, for example, 3:15 a.m. for the 6:30 a.m. forecast. Then, based on this information and some general observations, the mixing depth is predicted for the day. For an "it's-okay-to-burn" advisory, the mixing-depth forecast must be at least 4,000 feet deep.

Last year, the advisory program was revised to take into account such conditions as wind, temperature, humidity, and fire-danger ratings. Black points out that other meteorological conditions also could be forecast.

More research needed

Not all the questions raised by field burning have been answered. Further research is in progress, and more will be needed. For example, no interaction between burn date and the use of herbicides has been observed. Seed-yield increases due to herbicide application were proportionately the same on all test plots. But weed populations were rather low; future work may uncover some yield-affecting interaction.

Last summer, the field-burning trials were expanded to include six different grass species. Straw and stubble samples were gathered from each species early and late in the season. Preliminary findings indicate that the air-pollution potential is about the same with all species. However, analysis for the emission of various air pollutants indicates a somewhat greater output of hydrocarbons by late-season samples.

Also under way is a study seeking methods to improve the general management of Oregon's air resources through learning more about climate's effect on the state's major air-sheds.

Sampling device was used to determine type and amount of particles emitted during a test burn. Wires lead to power source and remote control unit.

Researchers are at work

in an effort to pinpoint precisely . . .

How Fluorine Affects Fruit Yield & Quality

Regulated amounts of gaseous flouride can be injected into special enclosures surrounding test cherry limbs.

INDUSTRIAL AIR POLLUTION may affect agricultural production, but it is easier to speculate about this than to prove it. A case in point is the scientific determination of the effect of fluorine, released in the manufacturing of aluminum, on the yield and quality of tree fruits.

While most plants readily absorb fluorine from the atmosphere, many vary in their sensitivity to injury from this element. This sensitivity may vary seasonally, too. Tree fruits, for example, may react more to fluorine during blossoming and fruit set than at other times. Further, the type of damage may differ with the amount of fluorine emitted, as well as with the season of emission.

Pinpointing the effects

One attempt to determine the effect of fluorides on fruit set, growth, and yield is beginning its fourth year in The Dalles area. Here, OSU horticulturists O. C. Compton and W. M. Mellenthin and agricultural chemist F. W. Adams are engaged in a series of controlled tests that they hope will pinpoint precisely effects of fluorine on tree fruits, particularly sweet cherries.

This work is an outgrowth of leaf-sample analysis that began in 1953—five years before an aluminum factory began operating in the area. These samples were analyzed for fluoride content to establish the normal level in crops grown there. The levels determined were used in turn as a base line from which the research workers might evaluate fluoride levels in the foliage after the aluminum factory started operations.

Monitoring fluoride levels in this fashion did not establish their effects on tree fruits, however. One problem was to determine unequivocally the symptoms of fluorine injury and how much such injury affected fruit set and yield.

Currently, special enclosures cover large cherry tree limbs in which low but regulated amounts of gaseous fluoride can be injected into the air surrounding the enclosed limbs. Because previous work indicated that cherry flowers were particularly sensitive to fluorides, special efforts are being made to treat cherry flowers (at different stages of development) with several airborne fluorine concentrations.

These experiments are being conducted outside The Dalles—in an area free of fluorine contamination but with a similar climate.

Already, this research has progressed sufficiently to describe the symptoms of injury to both leaves and fruit. Leaves of cherry trees exposed to a few parts per billion of hydrogen fluoride soon develop a "chlorotic" condition, in which light green to yellow areas develop between leaf veins. Leaf tissue is not killed unless higher amounts of fluoride are present. Cherry fruit exposed to relatively low hydrogen fluoride levels become slightly deformed and their tissue is much firmer than normal.

Procedures refined

Work has not progressed sufficiently to evaluate the effects of fluorine on fruit set and yield. Experimental design and procedures have been changed slightly as a result of experience. Because of the problems involved in providing adequate pollination, a small number of treatments repeated many times appears to be more efficient in providing useful information than the previous approach — many treatments tested only a few times.

The research workers hope that this experimental approach will help determine just what levels of airborne fluorine can be tolerated by sweet cherry trees, flowers, and fruits without injury or loss of production. Once these levels are found, perhaps industry and agriculture can both prosper in the same area.

Water Quality and the Recreation Economy

OSU study traces the economic impact of a decline in water quality on an area's recreation industry

HOW MUCH does water pollution cost?

This is not an easy question to answer—especially if it means a loss of income from recreational services. In recent years, however, economists have been devoting more and more attention to the complex economic problems of waste disposal and pollution. And new methods of economic analysis have been developed which make it possible to assess the effect of recreational services in an economy.

With the help of these new methods, OSU agricultural economist H. H. Stoevener and a team of OSU research workers have estimated what the impact of a decline in water quality, and a subsequent decline in sports fishing, would be on the economy of an area surrounding Yaquina Bay on the Oregon coast.

The total study area contains about 220 square miles of land and 15,000 residents, and includes the towns of Newport and Toledo. (The accompanying map excludes the study area's extreme northern and southern portions.) Newport is located at the mouth of the Yaquina Estuary. The tourist who visits to fish in the estuary is important to Newport's economy. During 1963-64, tourists spent about 60,000 man-days fishing for perch, greenling, flounder, salmon, and trout and clam digging and crabbing.

Toledo, on the other hand, is more industrial. For many years, timber processing has been the backbone of its economy. A more recent addition to industry in Toledo is a pulp and paper plant.

Large amounts of toxic liquid wastes are produced in manufacturing pulp and paper. In order to maintain water quality in Yaquina Bay, wastes from the Toledo plant are piped to an offshore disposal point west of Newport.

There has been considerable debate in Oregon recently on water quality. Much of it stems from the various economic considerations involved. Advocates of reduced purity standards have suggested that using the state's water for waste disposal represents a higher value use than if the water—kept free of wastes—were used for other purposes, such as recreation.

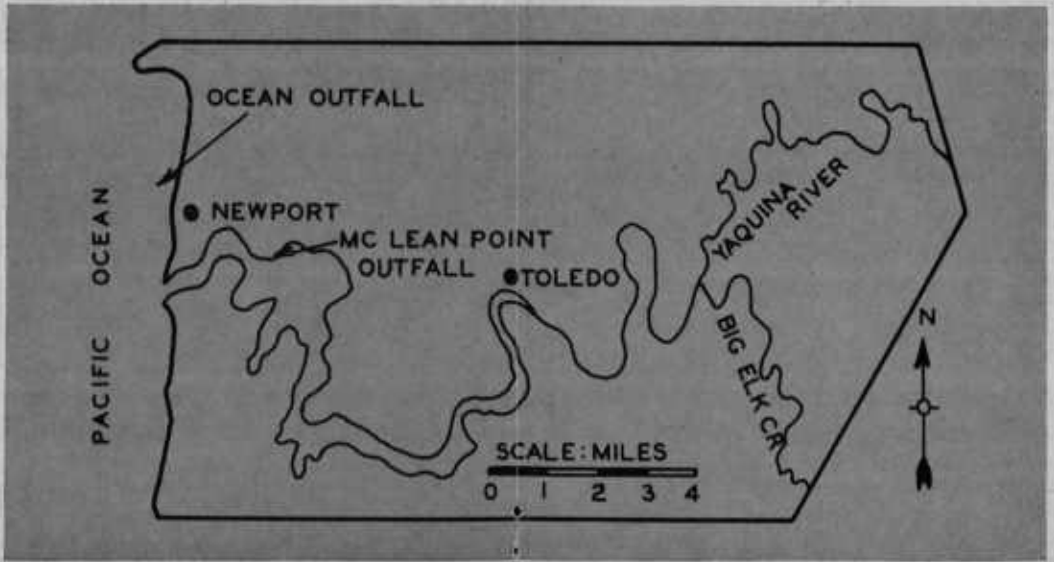
In response, advocates of higher purity standards have suggested that economic considerations also are attached to declines in recreation that result from a change in water quality.

Multiplier effects

If, for example, a fisherman no longer can catch fish in an area following a decline in water quality, he is likely to try his luck elsewhere. If he does, this will have a direct effect on the incomes of most individuals who sell fishing tackle or rent fishing boats in the area. But due to what are known as secondary or multiplier effects, the fisherman's exit means a good deal more.

The individual who sells fishing tackle to the fisherman also buys goods and services, perhaps bait supplies and business insurance, from other individuals in the area. If his sales are reduced, his ability to purchase bait and insurance is reduced. In turn, the purchasing ability of the individuals who sell bait or insurance is reduced, and so on throughout the area's economy. In their study of the Newport-Toledo economy, the OSU researchers attempted to account for all of these effects.

The first step was to estimate the impact of recreational fishing, given the actual point of waste disposal and the resulting level of water quality. Based on interviews of users of recreation facilities at Yaquina Bay over a one-year period, it was estimated that $154,550 was spent in the study area during the year for food, motels, bait, boat rental, gasoline, and so forth. In other words, local businesses made $154,550 worth of sales to fishermen and others who were in the area chiefly because of the recreational resources of Yaquina Bay.



As noted, however, the economic effects of this figure can go much deeper. A local restaurant owner, who serves meals to fishermen, may buy his milk from a local grocer and hire a waitress who is a local housewife. The grocer may get his supply of milk from a local dairyman, while the waitress uses her paycheck to pay a bill from a local dentist. Obviously, how well any one of these individuals fares in the local economy is going to have an effect on each of the other individuals. To describe this type of complex inter-relationship, economists use the term "structural interdependency."

In the same way, structural interdependencies also exist between the various "sectors" of an economy. (A sector is a grouping of similar or related economic activities.) In this study, the Newport-Toledo economy was divided into 16 sectors, including such groupings as cafes and taverns, wholesale and retail product sales, hotels and motels, automotive sales and services, consumer households, construction, and professional services. Some 400 businessmen and householders in the area were interviewed to determine the pattern of their sales and purchases. From these interviews, the trading pattern of the area's economy was determined.

The researchers then set up a mathematical model which represented the trading pattern of the economy. By applying certain mathematical techniques to such a model, it is possible to pin down the nature of the structural interdependencies.

The model revealed, for example, that when sales of the hotels and motels sector increased by $100, sales increased by about $20 in the automotive sales and services sector, about $12 in the construction sector, and about $40 in the wholesale and retail product sales sector.

Given the actual level of water quality, $154,550 was spent by users of recreation facilities at Yaquina Bay over a one-year period. Suppose, however, that one of several alternative waste disposal points considered in the study had been selected instead. If the decision had been made to dispose of wastes from the pulp and paper plant at, say, McLean Point, located on the north shore of Yaquina Bay inland from Newport and downstream from Toledo, what would be the impact on the Newport-Toledo economy?

Sales loss estimated

The researchers estimate that spending by fishermen and others who use recreation facilities in the area would shrink from $154,550 to $108,645, a loss in sales of $45,905 due to the decline in water quality and associated recreational activities.

But when structural interdependencies between the economy's 16 sectors are taken into account, the initial $45,905 loss in sales results in a total sales reduction of $94,120. Thus, multiplier effects would generate an additional loss of $48,215 or slightly more than twice the decline in spending by recreational users.

Net income changes

It is important, of course, to recognize that a decline in water quality has a sizable effect on an area's economy. But recognizing it may be of limited value when it comes to making management decisions about wastes. Often more important is the effect of a change in water quality on the net income produced by an economy's resources, and the income received by the area's residents in the form of wages, salaries, profits, rent, and interest. With the change in water quality which would have resulted from dumping wastes at McLean Point, the mathematical model revealed a $17,603 annual drop in net household incomes in the study area.

It should be emphasized that this change in household incomes represents only the impact of a certain decline in water quality on the study area's economy. No other effects of a water-quality decline, such as the presence of objectionable odors or the impact on any activities other than recreational, have been considered.

Moreover, the model deals only with the impact of changes in water quality on the area's recreation economy as it exists today. If a broader, long-term view is taken, it is apparent that a number of additional values are gained by keeping water quality in Yaquina Bay at its present level.

Cut Stream Contamination With Careful Chemical Brush Control

AERIAL APPLICATION of herbicides is an economical and effective way to control brush on Oregon forest lands. Regardless of the primary use to which these lands are put, however, the important role of the forest as a watershed must not be ignored.

Research now being conducted by OSU agricultural chemist Logan Norris and OSU forest researcher Michael Newton, with the cooperation of the U. S. Forest Service, shows that herbicides can be used for chemical brush control in Oregon's forests with a reasonable degree of safety from stream contamination. But direct application to large, slower-moving streams must be avoided. The same is true for treatment of marshy areas.

A scientific basis

The studies are being made to provide forest managers with a scientific basis for the development of spraying policies which will help hold stream contamination to a minimum. Streams have been tested for herbicide contamination following dormant-season application of 2,4-D and 2,4,5-T in western Oregon, early summer application of amitrole near the coast, and early summer application of 2,4-D in central and eastern Oregon. Based on the estimate that 100 parts per billion of a phenoxy-type herbicide in a stream is a biologically safe level, these studies show that the use of herbicides in western Oregon probably is "safe" —that is, it poses little or no threat to fish or downstream water users. (A "biologically safe" level is defined as the concentration of herbicide that can be tolerated by fish and various members of their food chain for an extended period of time.)

In eastern Oregon, where concentrations of herbicides have exceeded 1,000 parts per billion on occasion, some short-term damage to fish or certain members of their food chain might result. Usually, however, these higher concentrations exceeded the biologically safe level for only a few days.

When herbicides are applied by aircraft to a brush-infested block of forest land, a small portion is always lost through volatilization and drift. An additional small amount of the spray falls directly on surface water. The bulk of the herbicide, however, is either intercepted by the vegetation or falls directly to the forest floor.

Of the material which is deposited on a leaf, for example, from 10% to 30% is absorbed and only a small percentage of this amount actually moves to other parts of the plant. Any herbicide remaining on or in the leaf, of course, eventually reaches the forest floor through rain washing or leaf fall. Thus, it is clear that the forest litter and the forest soil end up receiving most of an aerially applied herbicide.

Herbicide breakdown

Fortunately, laboratory tests have established that 2,4-D, amitrole, and 2,4,5-T are degraded or broken down by microorganisms in forest litter. Amitrole is almost completely destroyed in a few days, 2,4-D in a few weeks, and 2,4,5-T within a few months. Although different formulations of 2,4-D are degraded at slightly different rates, none of the formulations tested has shown prolonged persistence.

These studies also show that the presence in forest litter of diesel oil, commonly used as a carrier for phenoxy-type herbicides, does not influence the rate of 2,4-D breakdown. And in the laboratory, when DDT is applied with 2,4-D to forest litter, degradation of 2,4-D appears to be stimulated—for reasons yet unknown.

Streams monitored

In the field work, streams have been monitored for herbicide concentration on a large scale in the Siuslaw and Malheur national forests. Stream monitoring also has been conducted in the Siskiyou, Rogue River, Umpqua, Mt. Hood, Deschutes, and Ochoco national forests. In a typical study, several stream-monitoring stations are located at various points downstream from the area to be treated. Water samples are tested prior to herbicide application to determine if any residues are present from previous applications. Following treatment, intensive sampling is continued for about a week, then at longer intervals for several months—well into the fall and winter period of heavy precipitation. The methods used to analyze water samples permit determination of herbicide concentration to levels as low as one part per billion in the water.

From this field work, the following conclusions have been drawn:

¶ Some herbicide will be found in nearly all streams which flow through or adjacent to a treated area.

¶ The length of time a herbicide is found in a stream depends primarily on how rapidly the contaminated por-

Careful application of herbicides to forest lands will help hold stream contamination to "biologically safe" levels

Photo: U. S. Forest Service

tion of the stream is flushed with fresh water from untreated areas upstream.

¶ Little danger of stream contamination is presented by that portion of herbicide which reaches the forest floor. This is because the chemicals decompose rapidly and have only limited movement in the soil.

¶ The amount of herbicide in a stream varies according to the amount of stream surface exposed to sprays.

¶ Nearly all the herbicide in a stream results from direct application to the stream surface, not from subsequent runoff or leaching during periods of heavy rainfall.

Avoid marshy areas

Norris and Newton caution against treatment of marshy or other high water-table areas. This is the one instance where herbicides applied to the ground can enter a stream, simply because slight increases in the water table (due to rains) may cause overland flow of the contaminated water. Treatment of such an area in eastern Oregon resulted in herbicide concentrations that approached 1,000 parts per billion with a fairly long persistence.

Harvesting an adequate supply of timber from an available land area that is decreasing because of the many pressures of increasing population is a must. However, maintaining the forest in such a condition that it continues to yield an adequate supply of high-quality water also is a must. By designing herbicide treatments and laying out spray areas so that direct application to large, slower-moving bodies of water is avoided, forest managers can help hold contamination of Oregon streams to a minimum.

Specially designed outdoor ponds will enable scientists to study fish at different oxygen concentrations under conditions closely akin to nature.

How Oxygen Level Affects Fresh-water Fish

FISH, LIKE PEOPLE, need oxygen to survive. If you threaten the supply of oxygen in the water, you threaten the supply of fish.

The capacity of Oregon's inland waters to support fish is constantly being threatened by the introduction of wastes that reduce the supply of dissolved oxygen. When waters receive large amounts of these wastes, dissolved oxygen can be reduced to low levels for long periods of time. Wide daily fluctuations of oxygen concentrations which involve brief low-level periods also may occur. This threatens fish life, too.

How changes in dissolved oxygen concentration affect fresh-water fish is being studied by OSU researchers Peter Doudoroff, Dean Shumway, and Charles Warren. The goal of the project and similar studies in progress is to make possible the establishment of sound water-quality standards that provide adequate protection for fish life.

The amount of oxygen that will dissolve in thoroughly aerated water is known as the water's "saturation level." While this level varies according to water temperature, at usual temperatures in Oregon waters it is approximately 10 parts of oxygen per million parts of water.

Fish avoid low oxygen

If fish are able to detect and avoid water with a low oxygen concentration, it follows that this will influence their distribution as well as help them survive under natural conditions. In tests at OSU, young coho (silver) and chinook salmon, largemouth bass, and bluegills show a definite and prompt avoidance of reduced oxygen concentrations. Cold-water salmon, particularly the chinook, respond very rapidly to low oxygen and avoid levels as high as 4½ parts per million. Warm-water bass and bluegills clearly avoid concentrations around 1½ parts per million and lower. Under natural conditions, however, fish are not always able to avoid water that is low in oxygen.

For a fish to succeed in its natural environment, it must be able to swim without serious difficulty. There are predators to escape, food to catch, rivers to migrate, and many other strenuous jobs to do. The effect of dissolved oxygen levels on the ability of fish to swim has been determined in tests at OSU's Oak Creek Laboratory.

Both warm-water and cold-water fish can swim at moderate speeds for 24 hours when oxygen concentrations are not much higher than necessary for survival. However, a coho or chinook salmon's maximum sustained swimming speed decreases if the concentration falls even slightly below the saturation level. The highest sustained swimming speed of largemouth bass is decreased only at somewhat lower oxygen concentrations.

When it comes to a quick, all-out burst of speed, coho salmon can sustain it significantly longer at high oxygen concentrations.

For natural reproduction and maintenance of a fish population, environmental conditions must be right. But because their eggs and fry develop in stream-bed gravels, salmon and trout are often endangered by conditions which restrict percolation of oxygen-laden water through these gravels. Both silt deposits and the presence of organic matter in stream water can reduce delivery of oxygen to eggs and fry.

In the Oak Creek lab, salmon eggs have been hatched successfully at oxygen concentrations as low as 2½ parts per million. However, exposing eggs throughout their development to oxygen concentrations below the saturation level results in delayed hatching and smaller hatching fry. Reducing the rate of water flow past eggs has a similar effect. Although fry are less sensitive to reduced oxygen levels after hatching, they still are quite sensitive when water velocity is low.

There also are signs that the small fry which result from poor rearing conditions may not tolerate the rigors of a natural environment as well as the larger fry that emerge from the gravel earlier.

For a fish to grow, the environment must not only provide sufficient food, but be such that the fish will want the food and be able to catch it and convert it to flesh. Changes in the environment can influence the abundance of food, the appetite of a fish, and its ability to catch food and make efficient use of it. Do changes in the level of dissolved oxygen make a difference?

During most of the experiments, food was readily and continuously available to the test fish. A drop in dissolved oxygen below the saturation level results in a loss of appetite (less food intake) and in reduced growth for both coho salmon and largemouth bass. This growth reduction is due chiefly to the smaller amount of food consumed, rather than poorer use of it. Dissolved oxygen concentrations well above the saturation level—this can occur naturally under certain conditions—also reduce appetite and growth of test fish.

Weight gain affected

Wide daily fluctuations in oxygen concentrations also make a difference, even when average concentrations are neither low nor high. Fish exposed to low concentrations at night and high concentrations during the day for two-week periods do not gain much more weight than if they are held at the low concentrations for the entire two weeks.

Graduate student Floyd Hutchins feeds young coho in test of growth ability.

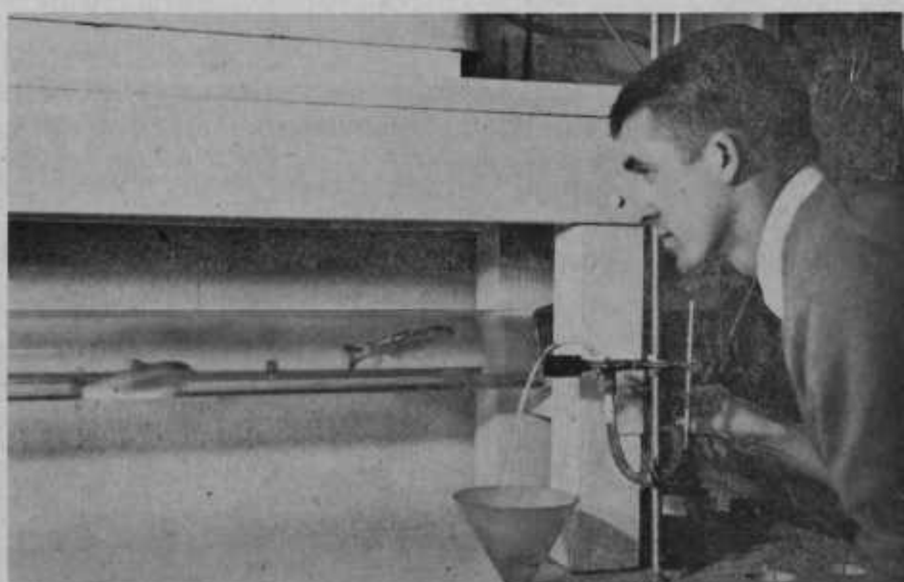
When coho salmon are held at varying oxygen concentrations on an identical, limited diet, little or no difference shows up in the growth rate of fish at high and moderately reduced levels. Only fish exposed to the lowest test concentrations show impaired growth due to poorer use of food. This indicates that when the supply of food is limited in a natural environment, moderate drops in dissolved oxygen may not seriously affect fish growth. When there is plenty of food, however, the effect of lower dissolved oxygen concentrations probably will increase.

Many valuable facts have been learned in the Oak Creek tests. Still, the researchers point out that laboratory studies are one thing, studies in nature another. You cannot assume that fish will react to reduced oxygen concentrations in a stream the same way that they react in a laboratory where there is no need to reproduce, seek food, escape predators, or migrate.

Natural conditions

Fish were able to exist—although barely—at very low oxygen concentrations of one to two parts per million in the tests. Under natural conditions, a population of fish can hardly be expected to maintain itself at such low concentrations. Fish reproduction, activity, growth, and movement cannot be seriously restricted by reduced oxygen levels without seriously threatening fish production.

To satisfy the need for further work, the OSU scientists are setting up additional experiments. Fish will be studied at different oxygen concentrations in specially designed outdoor ponds and streams under conditions closely akin to nature. Other tests, already in progress, will determine the ability of fish to grow at different oxygen concentrations when they are given differing amounts of food and forced to swim against varying currents. This work will help uncover more facts aimed at understanding how the introduction of wastes to inland waters may be affecting Oregon fish life in its native environment.



OSU researcher D. L. Shumway checks fish swimming ability in water of varying oxygen concentration which is pumped through tube at varying velocity.

An Ally in the War on Waste

Research has uncovered a remarkable aquatic insect which may make possible improved treatment of organic wastes

AQUATIC INSECTS are important weapons in the battle to break down domestic sewage and other organic wastes before they enter waters. Some insects, however, are better weapons than others.

One of Oregon's most effective waste-fighting insects, pinpointed recently by OSU researchers, turns out to be a chironomid midge or small mosquito-like fly with the scientific name of *Glyptotendipes barpipes*. Working to learn more about this potentially important enemy of water pollution are entomologists R. L. Goulding, N. H. Anderson, and R. A. Kimerle.

Waste-stabilization lagoons are being used more and more to handle domestic sewage and certain industrial wastes. In recent years, more than 30 such lagoons have been developed in Oregon to augment existing sewage disposal programs or to eliminate direct contamination of streams by raw sewage.

Treatment of organic wastes by bacterial oxidation or breakdowns is the oldest disposal method known. In fact, the process has been occurring naturally in streams, rivers, ponds, and lakes ever since life began. Briefly, here is how it works.

Aerobic bacteria

When adequate oxygen is available, sewage is broken down by the action of aerobic (oxygen-requiring) bacteria. In the course of their metabolic activity, these bacteria release abundant carbon dioxide and nutrients which, in the presence of sunlight, generate dense growths of algae. In turn, the algae give off oxygen in the process of photosynthesis. This oxygen is used by aerobic bacteria to complete the cycle.

If this biological cycle is managed properly, domestic sewage can be transformed into a reasonably acceptable material in our environment. Despite this considerable improvement, however, pollution still may result if the material is mishandled following treatment. For example, water discharged from a waste-stabilization lagoon remains fertilized with nitrogen and phosphorus. This can lead to undesirable growth of vegetation in waters receiving the discharge.

R. A. Kimerle takes sample of lagoon bottom to determine its midge density.

Insects contribute in several ways to the breakdown of wastes in oxidation ponds. Water mixed by free-swimming insects helps diffuse oxygen to deeper zones of a pond, where it is most needed by aerobic bacteria. Larval insects eat dying algae that no longer produce oxygen, thus reducing the amount of oxygen-consuming material. They also cause a beneficial mixing of oxygenated water into sediments at the bottom of the pond.

Gases released

Although waste-stabilization lagoons —much the same as septic tanks—will function without available oxygen, this type of lagoon usually is not acceptable. Sewage in such a lagoon is broken down by anaerobic, rather than aerobic, bacteria which release hydrogen sulfide, methane, and other gases in the course of their activity. Foul odors and generally offensive conditions can result. Moreover, the discharge from such a lagoon is intolerable in streams and rivers. Successful management of a waste-stabilization lagoon, then, depends on the maintenance of high levels of dissolved oxygen in the lagoon. And it is here that the insect plays its major role in turning domestic wastes into a more acceptable material.

However, an oxidation pond is a special habitat that requires organisms to have special characteristics in order to survive. With a virtually unlimited food supply, the two or three insect species that adapt best can multiply rapidly under some conditions of management. The result may be annoying mass flights of insects through surrounding neighborhoods or troubles with pests like emerging mosquitoes.

OSU entomologists have been working on some aspects of this problem since 1963. Last year, new and broader studies were launched.

A survey of insect species in 21 Oregon lagoons was taken last spring, summer, and fall. Although species abundance varied, the predominant insect in every case was the chironomid midge, *G. barpipes*. Densities (the number of midges per square foot) ranged from one or two to more than 20,000 during the course of the survey.

Peaks in late summer

Seasonally, this midge is most abundant in late summer. It dies off through the winter months, reaching its lowest point in early spring. Winter mortalities apparently are the result of low concentrations of dissolved oxygen, although other causes may be involved. In general, populations of the other insects found—largely related midges—follow these same seasonal trends.

During the summer months, when some of the ponds became stagnant from excessive duckweed growth on the surface, insects that need dissolved oxygen — including midges — disappeared. At the same time, insect larvae which can use atmospheric oxygen, such as rat-tailed maggots and mosquitoes, became abundant. And in ponds where emergent vegetation was allowed to grow around the edges, dense populations of mosquitoes were likely to develop. Both of these undesirable conditions can be controlled with effective lagoon management.

A more detailed study of a single, large lagoon system is under way in cooperation with the city of Monmouth. The well-managed Monmouth lagoons, which serve about 3,000 people, always have provided an adequate degree of waste treatment with no reported problems. Even in some winter months, the system achieves a degree of treatment comparable to far more elaborate facilities.

The OSU researchers' primary goal in this study is to determine the contribution of the *G. barpipes* midge to this efficient operation. Research involves the relationship between the amount of dissolved oxygen in the lagoon and the density of larval midge populations.

Environmental conditions in waste-stabilization lagoons often eliminate many species of aquatic insects commonly found in standing bodies of water. A major factor, but not necessarily the only one, is the level of dissolved oxygen. At certain times of the year, particularly early winter, dissolved oxygen levels in a lagoon can drop to zero, and this is unsuitable for most aquatic organisms. However, the *G. barpipes* midge survives both seasonal and daily low concentrations of dissolved oxygen considerably better than other aquatic insects, and is able to make maximum use of the lagoon environment.

To keep track of dissolved oxygen levels in the Monmouth lagoons, the researchers have reworked an analyzing device so it will automatically record changes, thus eliminating a number of time-consuming laboratory tests. The analyzer, along with a temperature meter and appropriate recording equipment, has been installed at the test site. Once every hour, water is pumped from the lagoon's surface, mid-depth, and bottom. The water is then analyzed for dissolved oxygen and temperature, and the resulting profile is recorded.

The life cycle of the *G. barpipes* midge consists of an egg, four larval stages, pupa, and adult. In the spring, over-wintering larvae grow to the pupal stage and emerge as adults. These few adults then lay eggs, and the density of midges continues to increase throughout spring and summer.

By September, a maximum density is reached, when as many as 26,000 larvae per square foot have been observed. Late fall and winter months bring a decrease in numbers until spring, when the cycle begins again.

Midge is high in energy

During a period of maximum density, there were more than 600 million *G. barpipes* larvae and pupae in the Monmouth system's secondary lagoon. Their dry weight was in excess of 1,500 pounds, and they contained a remarkable 3.3 million plus Calories of energy in their bodies.

The emergence of adults in large numbers can create a nuisance, however. On a few occasions during the summer, thousands of adult midges will emerge and congregate around the lagoon dikes. They also lay many thousands of eggs that can be seen floating on the lagoon surface.

Monmouth city supervisor K. R. Martin, center, and scientists view test site.

Is it worthwhile to put up with this occasional nuisance? The answer, of course, involves another question: what portion of the energy contained in sewage is consumed during the midges' growth and development?

At this point in the studies, it is too early to estimate the amount of sewage solids consumed and altered in some way by midge larvae. It is possible, however, to estimate that of the 500 tons of raw sewage solids entering the Monmouth lagoon system each year, up to 10 tons are removed in the form of adult midges emerging from the waters. This amounts to 2% of the original organic matter entering the system.

Obviously, the amount of sewage solids consumed by midge larvae to produce the 10 tons of adults is much higher than 2%. How much higher remains to be determined, but the answer will have considerable significance in the battle to keep Oregon waters clean.

"An area may be so anxious to entice industry . . . it overlooks pollution potential"

(*Continued from page 3*)
chemical smog. And southeastern Oregon, while not heavily urbanized at present, is regarded as having the highest air pollution potential in the United States.

Among the other significant sources of air pollution is smoke produced by forest slash burning and agricultural field burning.

Animal waste problem increasing

The solid-waste problem of greatest concern in Oregon has been municipal refuse and garbage. Many municipalities in the state still employ open dump disposal procedures, and conduct open burning to reduce the volume of material. Abatement has progressed, however, and a number of municipalities have shifted recently to landfill operations, including some sanitary landfills. Another solid-waste problem is the increasing volume of animal manures involving nutrient runoff, odors, and flies.

The possible accumulation of pesticides is of prime concern in the land environment.

Increased knowledge of nature's biological and physical processes is vital to the development of a sound pollution abatement and control technology. But equally vital in the total picture are public policies and social institutions — governmental agencies, legal processes, and regional arrangements, for example. Unless an abatement program is economically feasible and pertinent institutions are so structured that they are both effective and politically responsive, increased knowledge and improved technology are likely to be of little consequence. Several research projects are in progress at the Oregon Station concerning these aspects of pollution control. (The article on page 8, "Water Quality and the Recreation Economy," summarizes one of the studies conducted in the social area.)

Perhaps the most common expression of this intricate relationship is the conflict between economic development and environmental quality. An area may be so anxious to entice industry that it overlooks the matter of pollution potential. But a subsequent pollution problem may deter further economic development. Real costs in production processes downwind or downstream may be involved. Recreation and tourism developments or potentials may be harmed. An undesirable environment may be created for prospective employees of a firm seeking a location for a new plant. The dilemma is obvious: if regulations are too strict, industry may be unwilling to establish in an area; if regulations are too lax, an area's environment may deteriorate to the extent that other activities and values suffer.

In the past, the benefits of clean water, pure air, and uncontaminated land were recognized, but seemed remote and of secondary importance. Today, however, public concern about the quality of our environment is widespread and intense.

How high a price?

The question has been asked: "How high a price are we willing to pay for environmental quality?" Some suggest that we should settle for nothing less than absolutely pure air, pristine water, and unconditional repeal of the "right to pollute." At the other extreme is a laissez-faire, "do-nothing" approach which would let the chips fall where they may. Realistically, the approach will have to be somewhere in between. It seems doubtful that we will be willing to pay the price of absolute goals. The cost in terms of economic opportunities foregone probably would be too high. And the ultimate cost of doing nothing about pollution surely would be too high.

The assimilative capacity of water, air, and land for the disposal of wastes is a valuable asset. We must learn how to use this asset without unduly sacrificing other values. Research has contributed substantially to this effort. It will continue to do so.

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