Originalarbeiten

(From the University of Agriculture in Vienna and the Suez Canal University in Ismaelia)

Potentiality for Soil Erosion Control and Improving Plant Production in Arid Zones*

3rd Communication: Technique of Application of Soil and Evaporation Inhibitors and Investigations of the Environmental Behaviour of These Substances

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(With 7 figures)

1. Problems and Present Level of Knowledge

Recently developed products, finished products and tankmixtures must be applied without any remarkable difficulties nor must they cause any risk to the environment (Neururer 1991, 1991 a). The fact that in literature the application technique of bitumen emulsions has been considered very difficult is thought the reason that bitumen has been only rarely used for agriculture (Neururer 1982). But bitumen has already been considered safe to the environment and bitumen substances are also used for lining water tanks or isolating water conduits (Österreichisches Bundesinstitut für Gesundheitswesen 1989). Together with their various emulgators and additives, the emulsions have been judged differently, sometimes classified even as dangerous (Stoye 1987). Concerning Sarea Soil Stabilizer, no publications about its environmental behaviour are available, whereas Sarea Evaporation Inhibitor has been assessed harmless (Calandra et al. 1976, Hobbs et al. 1975).

2. Material and Methods

2.1 Development of application technique

It was aimed at the development of a device for the application of bitumen, which should be nearly without any failure and should have a surface spraying capacity similar to that of field sprayers i.e. 2—3 ha per hour. At the beginning of the test period the emulsions had to be warmed up before spraying. Therefore the devices needed a heating equipment and an installation for continous circulation of the liquid. These installations, however, were saved afterwards when cold spraying had become possible after some new emulsions had been developed.

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Fig. 1: First suitable sprayer mounted to an Unimog for spraying of warm bitumen emulsions in agriculture, 1981.

It was not necessary to construct any devices for the Sarea Soil Stabilizer nor the Sarea Evaporation Inhibitor, because these products could be applied by commonly used sprayers or atomizers.

The following equipments were developed:

A tractor-mounted field device for the application of bitumen emulsions, where a special piston pump was installed into a field sprayer to spray cold bitumen.

Some spraying aggregates by analogy with road building in cooperation with Breining Company, Stuttgart, where a special device mounted to an Unimog was constructed in 1981. This device was equipped with a gas heating, a dosing feeder, a special bitumen pump and with a circulation bar where the nozzles could be turned off either centrally or separately (fig. 1).

Fig. 2: Further developed large device for surface or band spraying of warm bitumen emulsions.

Fig. 3: Spraying device to be mounted to tractors.

An efficient spraying device mounted to an Unimog for applying warm bitumen emulsions suited for surface spraying and band spraying (fig. 2). This device, too, was constructed in cooperation with Breining Company, Stuttgart, using the experiences gained until this time.

Also in cooperation with Breining Company, Stuttgart, some tractor mounted devices were constructed, by which bitumen emulsions could be sprayed by the farmer himself (fig. 3).

A self-propelled device used for spraying and atomizing in Egypt was developed in cooperation with Blaschke Company, Vienna (fig. 4). An atomizer originally used in fruit growing was converted into a device either used for spraying Bituplant emulsions, if equipped with a hose pipe and a spraying pistol, or for surface atomizing and spraying. A device less complicated could be constructed, because the new Bituplant formula had been available in the meantime. For the first time also special double fan nozzles were used by which a better film should be reached.

Fig. 4: Self-propelled atomizer and sprayer for the trials in Egypt.

Fig. 5: Tractor-mounted device meant for spraying or atomizing of bitumen emulsions.

Development of a tractor mounted device for applying cold bitumen emulsions of the Bituplant type (fig. 5), also in cooperation with Blaschke Company, Vienna. A completely new device for the use in Egypt was developed and constructed, by which both, surface atomizing and spraying can be done. Long hoses are mounted to two reels meant for spraying by pistol. This device consists also of the following special installations: filling by injector, large filling sieve with enormous filtering areas and a compressor for turning off the nozzles, if the device comes to a halt or is turned around, to avoid stoppage. The pump is driven by the power-take-off shaft of the tractor, whereas the compressor is propelled by a diesel motor mounted to the device. Standard fan nozzles (TeeJet 110.06) are used.

Also small devices were developed for fome trials. At the beginning of the test period the bitumen emulsions were applied to small plots by knapsack sprayers and atomizers as used for plant protection. Later on, some 5 l manual sprayers were constructed, equipped with spraying bars and fan nozzles (TeeJet 110.06).

2.2 Testing the environmental behaviour

2.2.1 Chemical and physical behaviour

The general behaviour of the products in regard to film stability duration of effect and natural cycle is investigated and assessed.

2.2.2 Influence upon soil microorganisms

The influence of the products upon the enzyme activity of the soil microbes determined by measuring the dehydrogenasis by triphenylformazane (TPF). In order to facilitate the detection of any eventual detrimental effect on soil microbes, a tenfold dosage compared to the normal one was applied to sandy soil. The enzyme activity of the microflora is given in µg of triphenylformazane (TPF). Measuring was repeated 6 times. These investigations were carried out by the Weed Research Institute of the Biological Federal Institute in Braunschweig, Germany.

2.2.3 Influence upon soil fauna

The tubifex test carried out by the Swiss Research Institute in Zürich-Reckenholz, and the compost worm test *(Eisenia foetida)* were done according to the OECD-Guideline nr. 207 (OECD 1984).

2.2.4 Evaluation of aquatic toxicity

Rainbow-trouts (*Oncorhynchus mykiss.* W., formerly *Salmo Salmo gairdneri* R.) representing final consumers of water (fish) were chosen as test organism, and each test was carried out according to the Austrian standard specification (ÖNORM) M 6263, part 2 (semistatic test). The investigation took 48 hours and test water was replaced after 24 hours. The mortality of the organisms was considered the test criterion.

Daphnia magna S., representing primary consumers was chosen for the test carried out during 24 hours, according to the Austrian standard specification (ÖNORM) M 6264. Therefore, the criterion of response was determined by the swimming ability.

Further tests were carried out by using unicellular primary producers (*Selenastrum capricornutum* P. — green algae), according to OECD-Guideline nr. 201 and ISO standard 8692. The inhibition of cellular propagation (compared to control) within 3 days was chosen for test criterion.

Pseudomonas putida M., representing destructive organisms, was used for assessing aquatic toxicity according to DIN 38412 part 8. Therefore, the inhibition of cellular propagation within 16 hours was considered the test criterion.

These tests were carried out by the Federal Institute of Water Quality (Bundesanstalt für Wassergüte) in Wien-Kaisermühlen.

2.2.5 Influence upon plant growth

Using the cress-root test and the root test, phytotoxicity was determined by biotests in the laboratory (Neururer 1972, fig. 6 and 7).

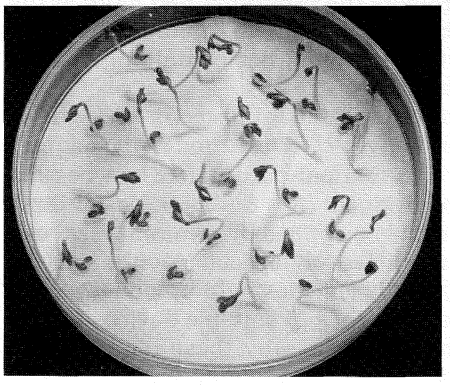

Fig. 6: Cress-root laboratory biotest for the determination of the phytotoxicity of a liquid.

Fig. 7: Root-test for assessing the phytotoxicity of a substance in the soil.

2.2.6 Crop rotation

The behaviour of the products within crop rotation (consisting of 3 succeeding crops) was assessed.

3. Results and discussion of the application technique

3.1 Application of bitumen emulsions

In the first trials, done in 1978, the bitumen emulsions were applied by a field sprayer equipped with a piston pump. But after a very short time the nozzles had got stopped and the pump was broken. Having then been equipped with a new type of pump, the sprayer resisted to the stress, but the dose feeder, the spraying hoses and the nozzles became permanently stopped. Therefore, this device was not suited for large surface spraying.

However, the device which had been mounted to the Unimog by Breining Company, meant for spraying warm bitumen emulsions, worked sufficiently when used for large-scale trials. The relative narrow width of the spraying bar was limited to 4 meters. But when a new efficient device for surface spraying had been constructed, the warm emulsions could be sprayed without failure. Using a dosage of 1500 l/ha, a spraying capacity of 1—2 ha/hour was reached. But for the farmer, who wanted to do his own spraying, a new device was needed which could be mounted to the tractor. Therefore, several successful tractor-mounted devices were constructed.

The device which had been changed from an orchard sprayer, proved suitable for the application of bitumen emulsions in Egypt. But very soon the plastic material became worm out, and also the cooling of the benzine motor, by which the rotary pump was propelled, became very difficult, due to high temperatures. Therefore, a new tractor-mounted device for spraying cold emulsions was constructed — once more in cooperation with Blaschke Company in Vienna — which was suited not only for spraying by pistol but also for surface atomizing and spraying. Based upon the experiences gained during the last 2 years and according to the development of bitumen emulsions and tank-mixtures, which can be better sprayed, less complicated and cheaper devices will be constructed in the future.

The knapsack sprayers used for treating small plots showed stoppage of nozzles, which led to the use of atomizers. But by the use of these atomizers the dosage was not exact, and due to the fine droplets the film remained more at the surface of the sand grains. Later on, for these trials some 5 l manual sprayers were constructed, which were equipped with a spraying bar containing several nozzles. So exact dosage was finally reached.

3.2 Discussion of the application technique

Any product can be successfully used in practice only if efficient devices are available. This concerned the non-bitumen products, the Sarea Soil Stabilizer and the Sarea Evaporation Inhibitor, which could be applied by common sprayers.

For the application of bitumen emulsions, however, special devices will be needed. Especially, if some agrochemicals, e.g. herbicides, will be added, exact dosage will be needed (Neururer 1984, 1984 a). The lack of suitable devices for the application of bitumen emulsions had been the reason why these methods had not been practically used long before. After some new bitumen emulsions had been developed which could be applied as cold ones, as "Bituplant 22", also less complicated devices were constructed. Based on the developments gained by cooperation with some companies during several years, some devices which showed similar capacity as those commonly used for plant protection, were constructed. This new type of device enables surface or band spraying as well as atomizing of Bituplant. Spraying is more effective, and the products will be dosed more exactly. Also for small areas suitable manual sprayers are available.

3.3 Results and discussion of the environmental behaviour

3.3.1 Chemical and physical behaviour

Bituplant 22: A short time (about half an hour) after having been applied, the bitumen emulsion will break at the soil surface and will form an irreversible and semipermeable film, by which the exchange of air and water is made possible. Having been decomposed by photolysis and by microbes, after 2 to 3 months this film will have mostly disappeared from soil surfaces and will have lost its original function. (NEURURER 1982). The rest of the bitumen particles will remain within the soil sometime longer and will behave similarly to humus colloids, i.e. adsorption as well as desorption will be observed. But due to the low dosage rates of 1000 to 3000 l/ha, exchange capacity will not be influenced.

Sarea Soil Stabilizer: Compaction of the top soil layer will last for about 2 months. In the meantime, the nutrients (20—22 % of N, 4—5 % of K_2O, 5—6 % of P_2O_5) of the products will be taken in by the plants, and so the product will be included into the natural cycle. The content of nutrients has to be considered for calculating the fertilizers.

Sarea Evaporation Inhibitor: For 2 to 3 months the evaporation inhibiting layer will remain effective in the top capillary layer of the soil and will be chemically decomposed. This will lead to natural products occuring in the environment, after the decomposed products will have been catalysed. The high stability of the isolated polydimethylsiloxane molecules will soon be lost (CALANDRA et al. 1976).

3.3.2 Influence on soil microorganisms

Table 1

Inhibition of dehydrogenasis

product	dosage/ha	mcg TPF	%
Control	—	315.5	100.0
Bituplant 22	30 000 l	476.0*)	150.9
Sarea Soil Stabilizer	1 000 kg	356.9	112.0
Sarea Evaporation Inhibitor	750 l	379.4*)	120.3

*) significant

The data given in table 1 are average values from 6 replications. For this test method any significance is given only, if there is a difference of 20 % between treated and untreated. Therefore, by none of the products, even if tenfold overdosed, any inhibition of the enzyme activity of the soil microbes was caused. On the contrary, enzyme activity was significantly promoted by Bituplant 22 and Sarea Evaporation Inhibitor. This soil conditioning effect of bitumen emulsions has been reported also in literature (BLÜMEL 1982).

3.3.3 Influence upon soil fauna

Table 2

Results of the tubifex test

product	LC_{50} $\bar{x}$ (n = 5)	s in %
Bituplant 22	12 000 mg/l	2.5
Sarea Soil Stabilizer	> 10 000 mg/l	—
Sarea Evaporation Inhibitor	> 10 000 mg/l	—

Due to easy handling, the tubifex is often used for quick assessment of the environmental toxicity of a product. The products listed in table 2 cannot be considered toxic to worms, because the test concentrations will never naturally occur. Within a few hours the products will irreversibly get compacted on the soil surface and will hardly move.

3.3.4 Influence on the compost worm (Eisenia foetida)

Table 3

Results of the compost worm test

product	dosage/ha	nr. of living animals after 14 days	
		$\bar{x}$ (n = 5)	s in %
untreated (control)	—	94	3.5
Bituplant 22	30 000 l	96	1.4
Sarea Soil Stabilizer	1 000 kg	95	2.0
Sarea Evaporation Inhibitor	750 l	97	1.2

Due to the fact that toxicity tests with *Lumbricus terrestris* have proved difficult, these tests were carried out by using *Eisenia foetida*, as often applied. 10 worms were added to 1 l of compost soil, which had been contaminated by a tenfold dosage. After 14 days their behaviour and their numbers were examined leaving the cocoons out of account. As it may be seen from the results given in table 3, even a tenfold overdosage did not cause any damage. If there had been any toxic reactions, it had been necessary to repeat the trials with *Lumbricus terrestris* in the field.

3.3.5 Influence upon water organisms

Aquatic toxicity was assessed according to the criteria of substance classification considering several degrees of water toxicity, as described by paragraph 19 of the law of water management (German Federal Republic 1987). Ecotoxicity of fish is determined by the lethal concentration 50 (LC_{50}), that of Daphnia by the effective concentration 50 (EC_{50}) and that of green algae and of bacteria by EC_{10}.

Table 4

Results of aquatic toxicity tests

organism tested	concentrations in g/l		
	Bituplant 22 $\bar{x}$ (n = 4)	Sarea SSS $\bar{x}$ (n = 4)	Sarea SEI $\bar{x}$ (n = 4)
Oncorhynchus, LC_{50}	0.7	2.4	0.50
Daphnia, EC_{50}	13.0	0.7	0.20
Selenastrum, EC_{10}	0.1	0.1	0.02
Pseudomonas, EC_{10}	10.0	0.4	0.50

The data given in table 4 are converted into evaluation coefficients (single results) and into water toxicity coefficients (arithmetic mean values of the evaluation coefficients), according to the criteria of substance classification as mentioned above.

Each of the 3 products can be considered slightly toxic to water and will therefore be classified by degree 1 of water toxicity.

3.3.6 Influence upon plant growth

Table 5

Results of laboratory biotests

product	cress-root-test ED_{50} ppm $\bar{x}$ (n=4)	s in %	root test method ED_{50} ppm $\bar{x}$ (n=4)
Bituplant 22	74 325	1.9	>100 000
Sarea Soil Stabilizer	8 750	1.8	>100 000
Sarea Evaporation Inhibitor	11 340	2.1	>100 000

As shown in table 5, very high ED_{50} values (50 % growth inhibition) are used. Therefore, the products can be considered safe to plants.

3.3.7 Behaviour within crop rotation

Table 6

Effect on crop rotation

soil type soil texture % of humus	crop rotation crop treated in 1986*)	succeeding crop 1987	1988	1989
colluvial brown earth sandy loam 2 % of humus	sugar-beet	cereals	rape	horse bean
colluvial brown earth loam 2.5 % of humus	maize	sugar-beet	cereals	potatoes
para brown earth loamy sand 1.5 % of humus	sugar-beet	cereals	maize	cereals
para brown earth loam 2 % of humus	sugar-beet	cereals	rape	sunflower
black earth sandy soil 3.5 % of humus	sugar-beet	carrot	maize	cereals

*) crop treated with 1500 l/ha of Bituplant,
100 kg/ha of Sarea Soil Stabilizer and
75 l/ha of Sarea Evaporation Inhibitor

The succeeding crops were visually estimated and their yield was compared to untreated control. Yield differences between treated and untreated did not exceed 7 %. It may, therefore, be deducted that the development of the succeeding crops was not influenced by the treatments. The nutrient value of Sarea Soil Stabilizer was taken into account for calculating the fertilizers.

3.3.8 Emission of polycyclic aromatic hydrocarbons (PAH) from the bitumen film

The emission of polycyclic aromatic hydrocarbons (PAH, cycle numbers 4—6) is of some importance for the assessment of the carcinogenicity of a substance, among which various phenol compounds must be mentioned, especially benzo(a)pyrene. These problems have yet been thoroughly investigated in con-

nection with road building and with drinking-water supply. It was stated that neither from bituminous road surfaces nor from drinking water tanks, lined with bitumen, any measurable amounts of PAH are released into water. The content of PAH naturally occurring in ground water was not increased. It was shown by exact laboratory tests that drinking-water was not affected by PAH, which had been leached out from recycling asphalt. The following natural amounts of benzo(a)pyrene were measured (see table 7):

Table 7

Natural amounts of benzo(a)pyrene

products	mcg/kg benzo(a)pyrene
coconut fat	up to 43.7
roasted sausage	up to 86.4
garden bean	90.0
arable soil	900.0
groundwater	10—50

3.4 Estimating the risks of environmental behaviour

According to the toxicity data determined for Bituplant 22, Sarea Soil Stabilizer and Sarea Evaporation Inhibitor and according to the exposition and dosages which are practically used, no potential danger for the environment is given. This has been pointed too by the low toxicity of the substances, which are located in the top layer of the soil, and by their compaction and decomposition within 2 to 3 months. In principle, a direct contact of the products to soil microorganisms, to soil fauna, seeds and plant roots will be possible by exposition and compaction on the soil surface. However, toxicity tests with tubifex, compost worm, garden cress, ray and tests of the enzyme activity of the soil have shown that even if there is a direct contact with the substances not yet compacted, danger will either not exist or be negligible. On the contrary, the activity of dehydrogenasis was even promoted by the products. Water organisms will be contacted only if rests of spraying liquids or rinsing water will be poured into the water against the rules. But even then, due to very low toxicity values water organism will not get impaired.

Any accumulation may also be excluded. The emission of carcinogenic polycyclic and aromatic hydrocarbons may be considered harmless, as reported about asphalt used for road building and lining of drinking water tanks.

According to the present level of knowledge, Bituplant 22, used at a dosage of 1500 to 3000 l/ha, Sarea Soil Stabilizer, used at a dosage of 100 kg/ha, and Sarea Evaporation Inhibitor, used at a dosage of 75 l/ha, will therefore not be of any risk neither for ecology nor for the environment.

Summary

Recently developed bitumen emulsions, as Bituplant 22, may be sprayed either in cold or warm state, if there are — similar to plant protection — suitable devices. These devices, having been developed during several years, are now available.

Sarea Soil Stabilizer and Sarea Soil Inhibitor can be sprayed either by special devices, combined with Bituplant 22 as a tank mixture, or can be applied separately by common plant protection devices.

Due to low toxicity, to the mode of degradation and to the exposition of the products, the use of Bituplant 22 at a dosage of 3000 l/ha, of Sarea Soil Stabilizer, at a dosage of 100 kg/ha, and of Sarea Evaporation Inhibitor, used at a dosage of 75 l/ha, will not cause any risk to ecology or environment.

Möglichkeiten zur Verhinderung der Bodenerosion und Verbesserung der Pflanzenproduktion in ariden Klimagebieten

3. Mitteilung: Technik der Ausbringung von Bodenfestigern und Verdunstungshemmern sowie ihr Verhalten in der Umwelt

Zusammenfassung

Neu formulierte Bitumenemulsionen, wie Bituplant 22, können — ähnlich wie Pflanzenschutzmittel — mit geeigneten Geräten kalt verspritzt oder versprüht werden. In mehrjähriger Versuchsarbeit wurden die notwendigen Geräte hiefür entwickelt und stehen nunmehr der Praxis zur Verfügung.

Die nicht-bituminösen Produkte Sarea-Bodenfestiger und Sarea-Verdunstungshemmer können sowohl als Tankmischungen mit Bituplant 22 mittels Spezialgeräten als auch alleine mit gewöhnlichen Pflanzenschutzgeräten appliziert werden.

Aufgrund der Toxizität der Produkte, ihres Abbauverhaltens und der Exposition der Stoffe stellt die Verwendung der vorgesehenen Aufwandmenge von 3000 l/ha Bituplant 22, 100 kg/ha Sarea-Bodenfestiger und 75 l/ha Sarea-Verdunstungshemmer kein Risiko für den Naturhaushalt und für die Umwelt dar.

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